Gamifying the Eating Experience: An Interactive Companion for Children's Nutrition Education and Behavior

Erin Lew, Jevrin Alviando, EunSook Kwon, and Jorge D. Camba(✉)

Gerald D. Hines College of Architecture and Design, University of Houston, Houston, TX, USA
{eplew, jalviando, ekwon, jdorribo}@uh.edu

Abstract. We present an interactive companion for children's nutrition education that capitalizes on digital technology to promote mental and physical stimulation by adding game-like elements to the eating experience. Our device allows children to manage portion sizes easily and promotes the practice of healthy eating habits by interacting with "Cibo," a healthy kid metaphor that encourages children to learn how different food groups benefit the body. Different parts of the device provide active feedback as the child eats his/her meal. The combination of physical and digital interaction gamifies the eating experience and redefines "playing at the dinner table" into a positive event that nourishes children physically, cognitively, and emotionally.

Keywords: Nutrition education and training · Playful interfaces · Educational technology · Child development

1 Introduction

For the past three decades, the prevalence of childhood obesity has significantly risen worldwide (see Fig. 1) [1]. According to recent statistics, nearly one out of every three children in the United States between the ages of two and nineteen is now overweight or obese [1, 2]. Childhood obesity occurs when the child's body mass index is equal to or greater than the ninety-fifth percentile [2]. Obese and overweight children are at risk of developing type-two diabetes, asthma, and heart disease later in life [3–5]. Being obese as a child is also a major risk factor for being obese as an adult [6].

The main contributing factors for childhood obesity include the increased access to processed foods, lack of physical activity, social and cultural factors, and an increase in portion sizes [7]. Consequently, most intervention studies for child obesity prevention involve strategies that focus on developing healthy eating habits and promoting active classroom activities such as sports and physical play. Researchers agree that successful interventions should involve home, school or kindergarten, and community participants [8–10].

In recent years, the idea of giving children more independence starting at a younger age is gaining popularity among many parents. In the Baby-Led Weaning approach (BLW), for example, parents encourage their infants to feed themselves so they can

P. Zaphiris and A. Ioannou (Eds.): LCT 2017, Part I, LNCS 10295, pp. 462–473, 2017.
DOI: 10.1007/978-3-319-58509-3_36

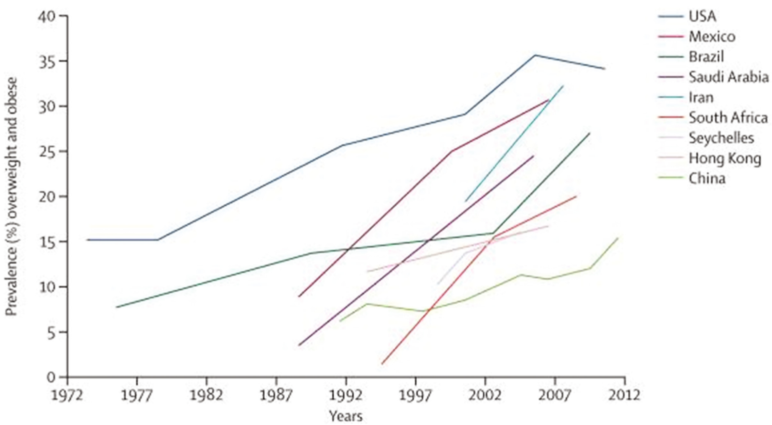

Fig. 1. Prevalence trends for childhood obesity in the USA and other countries [1]

proactively explore foods and develop their motor skills and independence [11]. During the preschool stage between three and six years old, children are naturally curious and inclined to do tasks without the assistance of their parents. The Montessori method of education uses the "whole child approach" which allows the child to experience the joy of learning and develop self-esteem through their experiences, which create their knowledge [12].

Montessori's holistic approach to school curriculum was greatly influenced by Piaget's theory of cognitive development [13] and Dewey's theory of childhood education [14]. Both theories stress the importance of children interacting with their environments to discover the world for themselves [15]. In the context of nutrition, if children could learn about the importance and the nutritional benefits of foods in relation to their bodies, healthy eating habits could be promoted at an earlier age.

In this paper, we describe the development of an interactive eating companion for children that uses gamification strategies to promote behavioral change. The device is designed to stimulate healthy eating by practicing portion control and familiarizing children with the nutritional benefits of the different food groups while encouraging independence.

2 Related Work

The terms "gamification" and "serious games" refer to the application of game-design principles to non-game contexts with the goal of improving user experience and engagement [16]. Simple game-like elements such as challenges, gratification and reward points, badges, and social encouragement have been applied to almost any situation that involves user interaction, including education [17], marketing and advertising [18], and business management [19], among others.

Some advantages of gamification include:

- Positive impact on the participants' emotional experiences [20].
- Enhancing the participants' sense of identity and social positioning [20].
- Encouraging active experimentation and discovery [20].
- Enhancing high-level social skills such as leadership, communication, and collaboration [21].
- Enhancing psychomotor skills [22, 23].

In health-related contexts, gamification has been applied to a variety of situations as a design strategy to promote behavioral change (i.e, promote wellness and reduce unhealthy/risky behaviors). For example, systems and devices such as Nike Plus or the Microsoft's Kinect sensor use game elements to promote and monitor physical activity. Mobile apps such as Slimkicker (http://www.slimkicker.com) or Fitocracy (https://www.fitocracy.com) turn diet, weight control, and fitness goals into gaming experiences. Many game-like applications have been developed to encourage personal hygiene [24] and good tooth brushing habits [25]. Significant efforts have also been made in the area of medication adherence and patient engagement [26, 27] as well as medical training and education [28].

Some schools and educational programs are making an effort to emphasize the importance of nutrition. However, the role of the parents is a large contributing factor as to why children are unaware of a healthy lifestyle. There is evidence that suggests that family rules have a significant effect on healthier eating habits and may serve as an intermediary mechanism to curb childhood obesity [29]. If healthy eating habits are reinforced and children appreciate the benefits of healthy foods, the habits will likely be sustained into adulthood.

Popular examples of the application of gamification strategies for promoting a healthy lifestyle among children include the Nintendo Wii console, which facilitates physical exercise through active gameplay [30], and the U.S. Department of Agriculture's 2013 initiative "Apps for Healthy Kids Competition." The competition "challenged software developers, game designers, students, and others to develop fun and engaging software tools and games that drive children to eat better and be more physically active" [31]. Winning submissions such as *Pick Chow!, PapayaHead,* or *The Snack Neutralizer* used game elements to motivate children to eat healthy and teach about the nutritional values of different foods.

Gamified systems that bring technology to the dining environment have also been proposed. For example, technology-based dining tables and plates have proven successful in helping children improve their eating habits [32, 33]. Similar approaches such as the computer-augmented tableware "EducaTableware" [34] provide auditory feedback when a user eats or drinks.

Commercially, one of the most well-known examples of technology-based hardware to train better eating habits is the "HAPIfork" [35], a smart fork that provides haptic feedback for the rate at which the user eats.

In this paper, we focus on the incorporation of digital elements to a children's dining tray. The goal is to teach correct portion sizes and allow precise measurements for extreme users that may have health and dietary restrictions. The target age range for our study is three to six year olds or the preschool range, as this is when children can start developing lifetime habits. Our concept seeks to provide an engaging mechanism to motivate the youth to learn proper portion control for developing better eating habits in the future.

3 Design Concept

A number of informal interviews were conducted with a group of parents and their elementary school age children to gain a better understanding of the most common approaches to nutrition education at the dining table from a parent perspective. Three key ideas were reoccurring in these conversations. In general, parents want their children to (1) finish the food on their plates, (2) eat a moderate pace, not too fast or too slow, and (3) keep their attention at the dinner table. In many cases, solutions to these problems involve negative actions such as bargaining, punishment, and letting the children have their way for having toys at the dinner table.

Additionally, registered dietitians and certified nutritionists were also interviewed about recommended portion sizes for children and the tools used to teach those measurements. According to these professionals, a typical child's plate is approximately seven inches in diameter. The recommended serving size for protein is the size of a deck of cards, which occupies one fourth of the plate. Grains should also occupy one fourth of the plate, whereas fruits and vegetables will fill half the plate. Although the market is crowded with children's plates that are divided into these three sections (which are generally a good way to start teaching proper portioning to children), it is too easy to pile the food high while still having the three divisions.

The data collected from the interviews was used to guide the development of "Cibo," a tool for child nutritional education that gamifies eating and incorporates physical interactions with a digital interface. Our first design concepts were inspired by traditional segmented plating to emphasize the visual aspect of managing food proportions, and popular child feeding practices such as the use of transportation vehicle metaphors (e.g. planes or trains). However, to emphasize the educational and teaching aspects of the design, a decision was made to make the final concept resemble a traditional storybook: one page with an interaction (e.g., reading) and the other page with visual feedback (e.g., pictures). As the child interacts with the food, the image on the left part of the board will display how the child's action and participation are being rewarded.

Our proposed device takes the form of an interactive tray or dining board that mimics a digital scale which is inspired by the well-known saying, "eat a balanced meal." The board is controlled by an Arduino microcontroller and is battery powered so it is portable and can be used when there is no outlet available. Settings on the board allow the parent to specify the desired age group for the child.

Visual feedback is provided by a group of LEDs inside “Cibo’s” silhouette. The LEDs are based on the WS2812 integrated light source, which uses a built-in driver and a single-wire control protocol to allow each pixel to be uniquely addressed. The light emitted by the LEDs is diffused by a plastic cover to create smoother light transitions.

The board is divided into two main areas. The right side of the board accommodates four force sensitive resistors calibrated to detect a range of values that correlates to the appropriate weights of a healthy serving size of the four main food groups. The left side provides a visual representation of our character “Cibo” which represents a healthy and happy kid that gives real-time feedback as the child is eating his or her meal. The character’s happy face and raised arms show strength and excitement. The idea is to incentivize children to finish their meals by presenting “Cibo” as a friend that

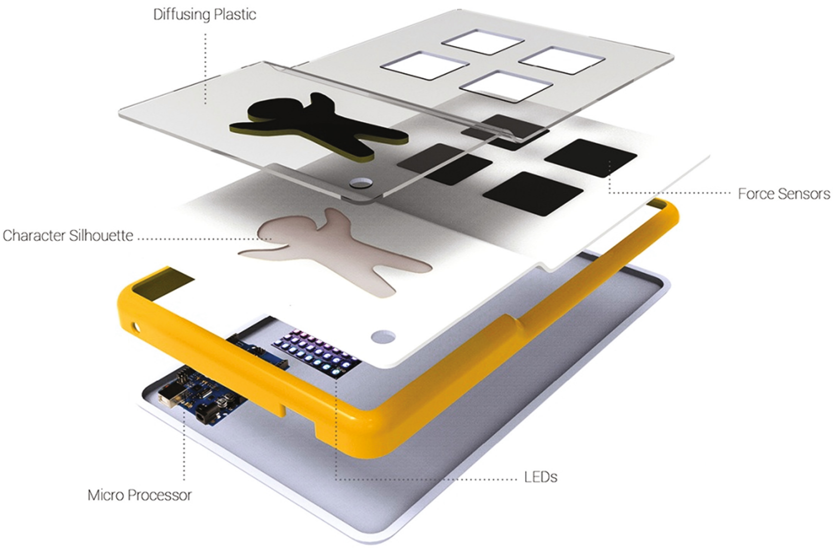

Fig. 2. Main components of the interactive board

needs to be taken care of. In order to see “Cibo’s” happy face and complete body systems, the child will need to eat the entire servings.

The left part of the board is slightly elevated with respect to the right side in order to separate the two main areas and bring the feedback interface closer to the child. The interface is comprised of four indicator lights, the character silhouette and body systems, and a button to begin the interaction. The main components of the device are shown in Fig. 2.

Four plastic bowls are used as food containers. All bowls have the same dimensions (3″ × 3″ × 2″) to encourage experimentation. Rather than visually showing which

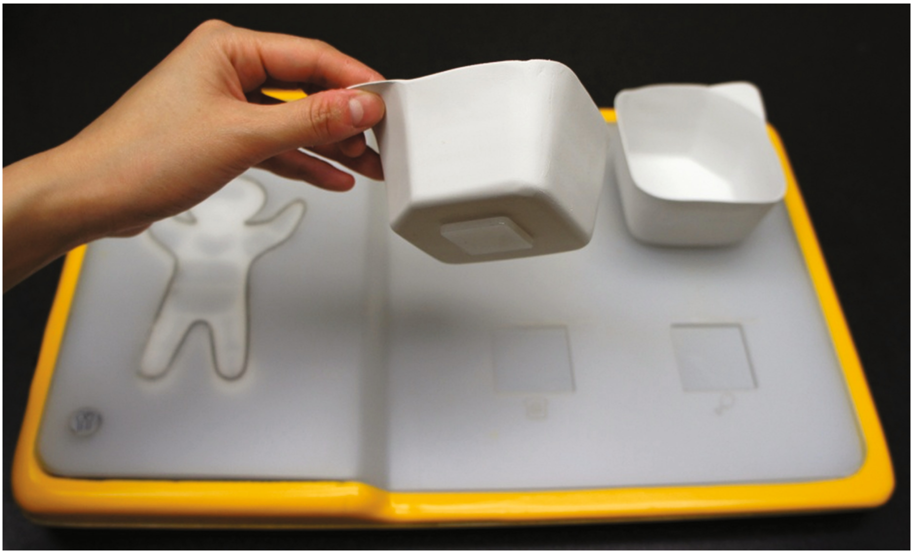

Fig. 3. Interactive board with "Cibo" character (left) and serving containers with flat bottom piece to facilitate contact with force sensors (right)

portions need to be bigger, children can explore and test different amounts as they serve themselves, thus training their eyes to recognize and estimate food sizes and serving amounts, which can help develop good habits as they grow older.

The bottom of each bowl has a flat square piece that makes contact with the force sensors and allows for an even weight distribution, which results in a more accurate reading (see Fig. 3). Graphic icons of the four food groups (fruit, vegetables, protein, and grains) are provided on the board to indicate the proper location of each bowl on the surface.

4 User Interface

The main interface elements of the board are shown in Fig. 4. The measurement indicator lights are mapped to the corresponding force sensitive resistor located on the right side of the board (e.g., the top left indicator informs about the status of the top left force sensor). The indicators are used to guide the serving process by providing feedback regarding the amount of food placed in each container. When the child does not serve enough food of a particular food group (i.e., in the appropriate container), the indicator will turn yellow. The light will change to red when the child has served too big of a portion. Only when the amount served in a particular container falls inside the calibrated range of a properly sized serving, the indicator will turn green. When all lights are green, the child can begin to eat and help "Cibo" grow healthy.

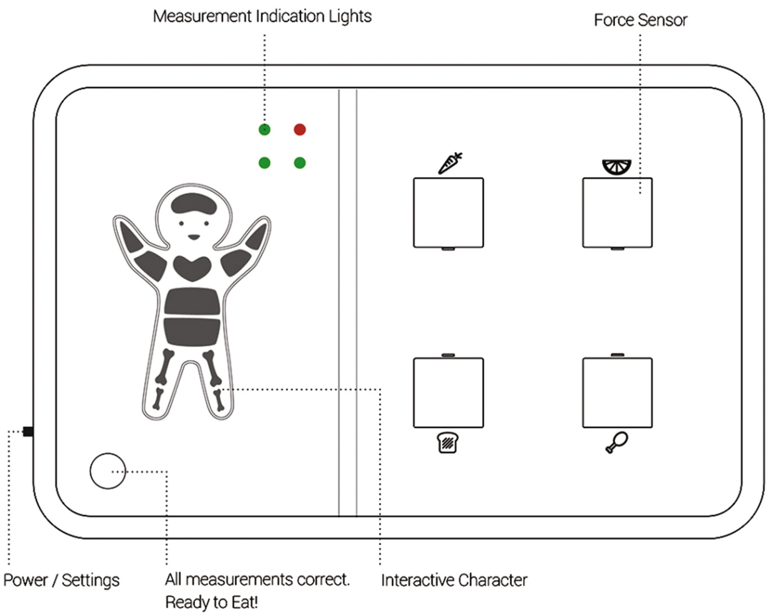

Fig. 4. Main user interface elements (Color figure online)

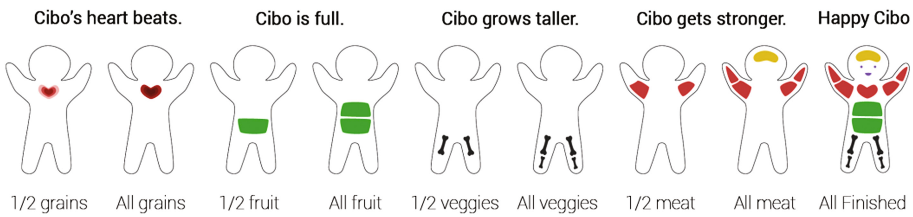

Fig. 5. Visual feedback provided by "Cibo"

The different feedbacks of "Cibo" are illustrated in Fig. 5. The bones, digestive system, muscles, heart, and brain glow as the child eats different foods. Eating grains from the grain container will start "Cibo's" heart and make it beat. Eating fruit from the corresponding container will help fill up "Cibo's" tummy. Eating vegetables will let "Cibo's" bones grow. Eating protein will let "Cibo" gain muscle in his arms and also feed his brain.

The type of interactive behavior and responses described above let the child learn what foods are good for the various parts and systems of the body. In addition, by having to complete "Cibo," the child is given an incentive to finish his/her meal. They can also eat to make "Cibo" a healthy kid as they nourish their own bodies.

5 Software

The two main components of the system in terms of software are the serving calibration process, which is required to establish a baseline for tracking how much the child is going to eat from each group; and the tracking process, which involves monitoring the force sensitive sensors and provide proper feedback mechanisms. Naturally, the serving calibration process will be performed first, before the tracking process. The predefined serving weights (MAX and MIN, in the algorithm) were portioned and recorded from a digital scale according to the serving sizes recommended by professionals.

The pseudocode for the main algorithms implemented in our prototype is provided.

```
Function Calibration() {
  For each Force Sensor Do {
    //initialize corresponding Indication Light(IL)
    TurnOff (IL);
    readyToEat = false; //proper weight reached?

    while (!readyToEat){
      ReadForceSensor(); //weight of the filled container

      if (ForceSensor <= MAX &&  ForceSensor <=MIN) {
       //Proper amount of food in the container
        readyToEat = true; //exit loop
        TurnOn (IL, "Green"); //notify user
      }
      else if (ForceSensor < MIN
              //Not enough food in the container
              TurnOn (IL, "Yellow"); //notify user
           else if (sensorValue > MAXIMUM VALUE
                   //Too much food in the container
                   TurnOn (IL, "Red"); //notify user
  }
}
```

When all measurement indication lights are green, the child can begin to eat. The tracking algorithm is responsible for monitoring the weight of each container and updating the "Cibo" character accordingly.

```
Function Tracking {
  For each Force Sensor Do {
    containerEmpty = false; //is the child done eating?

    while (!containerEmpty){
      ReadForceSensor(); //weight of the container

      if (ForceSensor = weightOfEmptyContainer) {
        //child has finished eating
        containerEmpty = true; //exit loop
        updateciboStatus(COMPLETE);
      }
      else if (ForceSensor = weightOfFullContainer / 2
       //container is half empty
        updateCiboStatus(HALF); //notify user
    }
  }
 }
```

6 Process of Use

The proposed device constantly monitors input from the force sensitive resistors located on the right side of the board. When the weight of each individual container filled with a specific type of food reaches a predefined limit (triggering the force sensitive resistors), the device will inform the child that “Cibo” is ready to be used.

The use cycle of the device is described in Table 1.

Table 1. Sequence of stages and actions in the use cycle of the interactive board.

Step	Action	Description
1	System setup	With the help of the parent, the board is switched on to a setting based on the age and size of the child
2	Food serving	Child will serve him or herself food from the different food groups into separate bowls
3	Container placement	The bowls are placed onto the correlating food group sensor indicated by the etched icons on the board surface
4	Initial feedback	Measurement indicator lights are shown over the Cibo character
5	Begin interaction	When all four indicator lights are green, they will flash indicating success in their first goal. The child will push the start button to begin eating and interacting with Cibo
6	Eating process	Force sensors will constantly read the current weight in the bowls. When the values drop to a range that indicates a half full bowl or an empty bowl, different body systems of Cibo will illuminate in response to the food group
7	Reset	When all the food is consumed, Cibo’s face will light up, which completes the process

7 Conclusions and Future Work

In this paper, we presented an interactive device for children nutrition education. The features combine physical nourishment, nutritional education, and playing at the table. The incorporation of a friendly character and game-like elements in the device encourages empathy and gives the child incentive to finish her meal and see her friend grow healthy and happy. The interaction between the child and the device helps the child understand the benefits of eating healthy while practicing independence.

Although informal evaluations and expert reviews suggest our approach might be an effective tool to encourage healthy eating habits in young children, the device remains untested with large sample sizes. Future testing will include wider studies across a broad demographic, both in home environments and educational settings such as schools and day cares. Testing is also needed to refine the interface, as the abstraction of the character may be confusing to younger children who have yet not learned general anatomy. A simple solution could include the visual customization of "Cibo" through interchangeable character silhouettes.

As future work, we would like to provide higher levels of adaptability to the device, as different children have different nutritional needs. For example, the two settings used to define the portion sizes (child age and size) could be accompanied by an additional option for snacks or for children with dietary restrictions such as a setting that does not activate the sensor responsible for the protein container for a vegetarian child.

Finally, it would be interesting to test the conditions under which the board and/or the interactions could be modified for children who are overweight, underweight, or have an eating disorder and need a strict diet or an activity to encourage healthy habits and bring delight, if eating is a difficult task.

References

1. Lobstein, T., Jackson-Leach, R., Moodie, M.L., Hall, K.D., Gortmaker, S.L., Swinburn, B. A., James, W.P.T., Wang, Y., McPherson, K.: Child and adolescent obesity: part of a bigger picture. The Lancet **385**(9986), 2510–2520 (2015)
2. American Heart Association: Overweight in Children (2016). http://www.heart.org/HEARTORG/HealthyLiving/HealthyKids/ChildhoodObesity/Overweight-in-Children_UCM_304054_Article.jsp. Accessed Mar 2016)
3. Lloyd, L.J., Langley-Evans, S.C., McMullen, S.: Childhood obesity and risk of the adult metabolic syndrome: a systematic review. Int. J. Obes. **36**(1), 1–11 (2012)
4. Mohanan, S., Tapp, H., McWilliams, A., Dulin, M.: Obesity and asthma: pathophysiology and implications for diagnosis and management in primary care. Exp. Biol. Med. **239**(11), 1531–1540 (2014)
5. Bacha, F., Gidding, S.S.: Cardiac abnormalities in youth with obesity and type 2 diabetes. Curr. Diab. Rep. **16**(7), 62 (2016). doi:10.1007/s11892-016-0750-6
6. Goldschmidt, A.B., Wilfley, D.E., Paluch, R.A., Roemmich, J.N., Epstein, L.H.: Indicated prevention of adult obesity: reference data for weight normalization in overweight children. Arch. Pediatr. Adolesc. Med. **167**, 21–26 (2013)

7. Centers for Disease Control and Prevention (CDC): Childhood Obesity Causes & Consequences. https://www.cdc.gov/obesity/childhood/causes.html. Accessed Mar 2016
8. Wang, Y., Wu, Y., Wilson, R.F., Bleich, S., Cheskin, L., Weston, C., Showell, N., Fawole, O., Lau, B. Segal, J.: Childhood obesity prevention programs: comparative effectiveness review and meta-analysis. Comparative effectiveness review no. 115. Agency for Healthcare Research and Quality, Rockville (2013)
9. Nixon, C.A., Moore, H.J., Douthwaite, W., Gibson, E.L., Vogele, C., Kreichauf, S., Wildgruber, A., Manios, Y., Summerbell, C.D.: Identifying effective behavioural models and behaviour change strategies underpinning preschool- and school-based obesity prevention interventions aimed at 4–6-year-olds: a systematic review. Obes. Rev. **13**, 106–117 (2012)
10. Khambalia, A.Z., Dickinson, S., Hardy, L.L., Gill, T., Baur, L.A.: A synthesis of existing systematic reviews and meta-analyses of school-based behavioural interventions for controlling and preventing obesity. Obes. Rev. **13**, 214–233 (2012)
11. Rapley, G., Murkett, T.: Baby Led Weaning: The Essential Guide to Introducing Solid Foods and Helping Your Baby to Grow Up a Happy and Confident Eater. The Experiment, LLC, New York (2005)
12. Montessori, M.: The Montessori Method. Transaction publishers, Chicago (2013)
13. Piaget, J.: The Child's Conception of the World, vol. 213. Rowman & Littlefield, New York (1951)
14. Dewey, J.: Experience & Education. Kappa Delta Pi, New York (1938)
15. Mooney, C.G.: Theories of Childhood: An Introduction to Dewey, Montessori, Erikson, Piaget & Vygotsky. Redleaf Press, Little Canada (2013)
16. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: defining gamification. In: Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, pp. 9–15. ACM. Chicago (2011)
17. Dicheva, D., Dichev, C., Agre, G., Angelova, G.: Gamification in education: a systematic mapping study. Educ. Technol. Soc. **18**(3), 75–88 (2015)
18. Terlutter, R., Capella, M.L.: The gamification of advertising: analysis and research directions of in-game advertising, advergames, and advertising in social network games. J. Advertising **42**(2–3), 95–112 (2013)
19. Robson, K., Plangger, K., Kietzmann, J.H., McCarthy, I., Pitt, L.: Game on: engaging customers and employees through gamification. Bus. Horiz. **59**(1), 29–36 (2016)
20. Lee, J.J., Hammer, J.: Gamification in education: what, how, why bother? Acad. Exch. Q. **15** (2), 2 (2011)
21. Read, J.L., Shortell, S.M.: Interactive games to promote behavior change in prevention and treatment. JAMA **305**(16), 1704–1705 (2011)
22. Biddiss, E., Irwin, J.: Active video games to promote physical activity in children and youth: a systematic review. Arch. Pediatr. Adolesc. Med. **164**(7), 664–672 (2010)
23. McConville, K.M.V., Virk, S.: Evaluation of an electronic video game for improvement of balance. Virtual Reality **16**, 315–323 (2012)
24. Lapao, L.V., Marques, R., Gregorio, J., Mira-da-Silva, M.: Nurses' self-improvement hand-hygiene compliance in a hospital ward: combining indoor location with gamification data presentation. Antimicrobial. Resist. Infect. Control **4**(1), I11 (2015)
25. Lee, N., Jang, D., Kim, Y., Bae, B.C., Cho, J.D.: DenTeach: a device for fostering children's good tooth-brushing habits. In: Proceedings of the 15th International Conference on Interaction Design and Children, pp. 619–624. ACM (2016)
26. Miller, A.S., Cafazzo, J.A., Seto, E.: A game plan: Gamification design principles in mHealth applications for chronic disease management. Health Inf. J. **22**(2), 184–193 (2016)

27. Theng, Y.L., Lee, J.W., Patinadan, P.V., Foo, S.S.: The use of videogames, gamification, and virtual environments in the self-management of diabetes: a systematic review of evidence. Games Health J. **4**(5), 352–361 (2015)
28. Graafland, M., Schraagen, J.M., Schijven, M.P.: Systematic review of serious games for medical education and surgical skills training. Br. J. Surg. **99**, 1322–1330 (2012)
29. Lederer, A.M., King, M.H., Sovinski, D., Kim, N.: The impact of family rules on children's eating habits, sedentary behaviors, and weight status. Child. Obes. **11**(4), 421–429 (2015)
30. Graf, D.L., Pratt, L.V., Hester, C.N., Short, K.R.: Playing active video games increases energy expenditure in children. Pediatrics **124**(2), 534–540 (2009)
31. U.S. Department of Agriculture: Let's Move! The Apps for Healthy Kids. http://appsforhealthykids.challengepost.com. Accessed Jan 2016
32. Lo, J.-L., Lin, T.-Y., Chu, H.-H., Chou, H.-C., Chen, J.-H., Hsu, J.Y.-J., Huang, P.: Playful tray: adopting Ubicomp and persuasive techniques into play-based occupational therapy for reducing poor eating behavior in young children. In: Proceedings of the 9th International Conference on Ubiquitous Computing, UbiComp 2007 (2007)
33. Mori, M., Kurihara, K., Tsukada, K., Siio, I.: Dining presenter: augmented reality system for a dining tabletop, In: Proceedings of the 11th International Conference on Ubiquitous Computing, UbiComp 2009 (2009)
34. Kadomura, A., Tsukada, K., Siio, I.: EducaTableware: computer-augmented tableware to enhance the eating experiences. In: CHI 2013 Extended Abstracts on Human Factors in Computing Systems, pp. 3071–3074. ACM (2013)
35. HapiFork: HAPI.com. https://www.hapi.com/product/hapifork. Accessed Mar 2016