

Digital-based Living Lab intervention to promote healthy dietary behaviours in adolescents

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Abstract

Digital health interventions are increasingly used to promote behaviour change in adolescents. The Living Lab approach, fostering collaboration with users and stakeholders to identify real-life problems and co-create sustainable solutions, is gaining traction in health interventions. This study aimed to evaluate the usability of a novel Digital-based Living Lab (D-LLab) designed to promote healthy dietary behaviour in adolescents. The D-LLab was developed in four phases: topic derivation, strategy selection, digital tool selection, and usability assessment. It was implemented over a 4-week period, structured into four participatory phases: identifying problems, exploring solutions, solving problems, and sharing outcomes. Twenty-one adolescents aged 14–16 from one middle school enrolled, with a balanced sample of racial and ethnic adolescents, and native Koreans. Usability was evaluated using a mixed methods approach, incorporating quantitative indicators—appropriateness (system usability scale, SUS), acceptability (satisfaction), and feasibility (completion rate)—alongside qualitative data on participant experiences. The mean SUS score was 70.75, exceeding the benchmark for acceptable usability. Participants rated high satisfaction (mean score: 8.45/10), and 95.2% completed all sessions. High usability appeared to be driven by real-time information sharing and collaborative digital interaction, which supported spontaneous problem solving around dietary issues. The D-LLab demonstrated acceptable usability and strong participant engagement. These findings highlight the feasibility of applying digital-based Living Lab approaches in school settings, warranting further trials to evaluate long-term behavioural impact across diverse populations. This intervention was registered at cris.nih.go.kr as KCT0007004.

Introduction

Digital technology has become embedded in adolescents' daily lives, with the COVID-19 pandemic further accelerating their engagement with mobile applications (Apps), social media, and web-based platforms [1, 2]. These tools are no longer limited to communication but serve as platforms for information exchange, peer interaction, and health-related behaviours [3]. Recently, along with the application of digital technologies in health management, methods to promote healthy lifestyles in a digitally transformed living environment are recognized as effective health solutions [4]. For adolescents, it is generally recognized that it has clear advantages such as being able to draw attention to health issues, actively communicate, disseminate ideas easily, and gain social support to achieve health goals [5].

As adolescence is a critical period of development complemented by rapid physical growth, proper nutrition management is important for a healthy transition to adulthood. Poor diets among adolescents are closely associated with the occurrence of health problems such as increased adiposity [6], adult obesity [7], and elevated risk of chronic diseases [8] in adulthood, indicating the need of interventions to promote healthy dietary habits in adolescents. According to 2021 statistics, South Korea has 160 058 adolescents who are racial and ethnic adolescents, accounting for 3.0% of all adolescents [9]. This number is about three times higher than the 2013 statistics of

55 780. They have even been identified as having more health vulnerabilities, including dietary problems, resulting from social determinants of health such as language, socio-economic status, acculturation, and support systems [10]. Given this rapid increase and health problems in racial and ethnic adolescents, interventions targeting adolescents must include this population.

Considering the characteristics of adolescence and focusing on enabling voluntary behavioural changes is critical to forming healthy diet habits. To date, traditional dietary interventions were structured and adopted top-down approaches, with externally designed content and limited opportunities for adolescent engagement [11–13]. These passive formats may fail to resonate with adolescents' lived experiences and do not adequately incorporate their sociocultural context. The Living Lab is defined as 'open innovation ecosystems in real-life environments using iterative feedback processes throughout a life-cycle approach of an innovation to create sustainable impact'. Through the Living Lab, users and stakeholders become citizen scientists and directly do everything from problem identification to fact-based solutions to develop acceptable and sustainable solutions that lead to behavioural change [14, 15]. Although this approach has been used extensively in chronic disease management and health promotion [16], their use in adolescents' dietary interventions remain limited, particularly in digital formats.

Moreover, as Living Lab approach, engaging both native and racial and ethnic adolescents as co-creators can be a way to reflect

the changing demographic characteristics of diverse adolescent populations. It is particularly suitable for minimizing the negative experiences occurring during the adolescent self-exploration period by preventing the stigma associated with interventions that single out minority groups [17, 18]. Additionally, combining the Living Lab approach with digital technology may enhance accessibility, increase engagement, and align with adolescents' lifestyles. A digital-based Living Lab (D-LLab), therefore, represents a novel and potentially effective strategy for promoting sustainable dietary behaviours among diverse adolescent population.

As digital health interventions continue to grow, the importance of usability assessment also increases to ensure that users can successfully accomplish intended outcomes in real-life settings [19]. Usability was defined as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use' [20]. Combining Living Labs with appropriate digital technologies for adolescent behaviour change is a new attempt and challenge for the digitally engaged adolescent populations. Therefore, it is essential to learn the extent to which D-LLab is useful in the context of the interventions using technology, and not just the technology used in health intervention. This study aimed to evaluate the usability of D-LLab interventions designed to promote healthy dietary behaviour among adolescents. Special attention was given to engaging both native adolescents and racial and ethnic adolescents as peer collaboration within a participatory digital health intervention.

Methods

Study design

This study evaluated the usability of D-LLab intervention aimed at promoting healthy dietary habits among adolescents, employing a mixed methods convergent parallel design.

Participants

Participants were recruited from a single all-boys middle school in Yongsan-gu, Seoul, South Korea. The sample included two groups: native Korean adolescents and racial and ethnic adolescents. A recruitment notice was posted on the school bulletin board with the help of a school counsellor, and students interested in participating in this study voluntarily applied via online application form.

A total of 27 adolescents (14 natives and 13 racial and ethnic adolescents) applied and were screened using inclusion and exclusion criteria. Natives must be born in Korea and have Korean citizenship, and their parents must also have the same conditions. Racial and ethnic adolescents must have been born in Korea or immigrated to Korea, and should be children of multiethnic families. All the participants could read and write in Korean. Adolescents without parental consent, those with chronic diseases requiring dietary therapy (e.g. type 1 diabetes), or taking medications affecting dietary behaviours were not allowed to participate in the study.

During the screening, two racial and ethnic applicants were excluded: one who could not communicate in Korean and one who did not wish to participate during the screening process. Four native adolescents also declined to participate prior to enrolment. Finally, 21 participants (10 natives and 11 racial and ethnic adolescents), aged 14–16 years, were enrolled in the study.

Measures

Usability was assessed across three operationally defined dimensions: appropriateness, acceptability, and feasibility. 'Appropriateness' was measured as perceived usability of the digital tools integrated into D-LLab—Zep, Jam board, and Padlet—using the system usability scale (SUS) developed by Brooke [21] and translated into Korean by Yoon *et al.* [22]. The SUS consists of 10 items evaluating perceived ease of use and acceptance of the technologies (e.g. 'I think

that I would like to use these systems frequently'). Each item was scored on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree) with total scores ranging from 0 to 100 after reverse-coding of negative items. A score ≥ 70 is considered as the minimum 'acceptable' level by Bangor *et al.* [23]. In this study, the Cronbach's alpha was .854. 'Acceptability' was defined as participants' overall satisfaction score with D-LLab and evaluated using a single-item 10-point Likert scale (1 = very dissatisfied to 10 = very satisfied), asking 'Are you generally satisfied with the D-LLab?'. 'Feasibility' was assessed based on the intervention completion rate—the proportion of enrolled participants who attended whole sessions and completed the post-intervention survey ('calculated as $n/N \times 100\%$ ').

To support the quantitative indicators, qualitative usability evidence was also collected in two ways: (1) brief open-ended questionnaires exploring perceived benefits of stakeholder engagement, changes in the attitudes towards other cultures, and overall impressions of D-LLab (e.g. 'During the D-LLab, which comment or action from a peer was the most helpful to you, and why?'); and (2) weekly reflections and the digital artefacts generated during each session (e.g. project plans, videos, slides).

Intervention

From October 2021 to May 2022, the intervention was developed through a four-step process: topic derivation, strategy selection, digital tool selection, and usability assessment (Fig. 1). The topic was derived from previous research that analysed secondary data obtained from the Korean Youth Health Behaviour Survey [24, 25] and the focus group interviews were conducted by the research team. Those findings revealed that adolescents from multi-ethnic backgrounds—due to contextual challenges such as dual-income parents and cultural differences—experienced more dietary and health-related problems (e.g. breakfast skipping, obesity, and poor subjective health) than their native peers.

The D-LLab was designed based on the principles of the Living Lab [14] and behaviour change technology frameworks [26]. Racial and ethnic adolescents were positioned as primary users, while native adolescents served as peer stakeholders. In addition, a variety of stakeholders, including teachers, school counsellors, and community representatives, were engaged to provide contextual insights and support [15]. On the advice of Living Lab experts, four groups of five to six people were formed, with similar proportions of native Koreans and racial and ethnic adolescents. Each group was supported by one trained facilitator—graduate nursing students who completed a 2-h workshop every week to reinforce adolescent-facilitation skills, Living Lab methodology, and hands-on practice with digital devices. The facilitator provided technical assistance and guided discussion with minimal intervention.

To support digital implementation, all participants received portable tablets. Digital education tools were selected based on teachers' recommendations drawn from their experiences, and included Zep (an avatar-based virtual classroom), Jamboard (a collaborative online whiteboard), and Padlet (a shareable multimedia pin-board).

The 4-week D-LLab intervention was implemented from May to June 2022. Sessions were held once weekly after school in a classroom setting, allowing face-to-face interaction among participants and facilitators while using digital tools. Each weekly session was structured: (1) identifying problems, (2) exploring solutions, (3) solving problems, and (4) disseminating solutions. In the first week, participants used online grocery shopping sites and 'why-why' chain template in Jamboard to raise awareness of healthy dietary habits and map personal dietary problems. In the second week, groups engaged in gallery walking activities in Zep, commented on peers' problem maps, and drafted action plans in Padlet. Then, each group selected an appropriate solution and wrote an activity plan. In the third week, actual activities were completed based on the written action plan—e.g. recording a healthy-cooking video or designing a

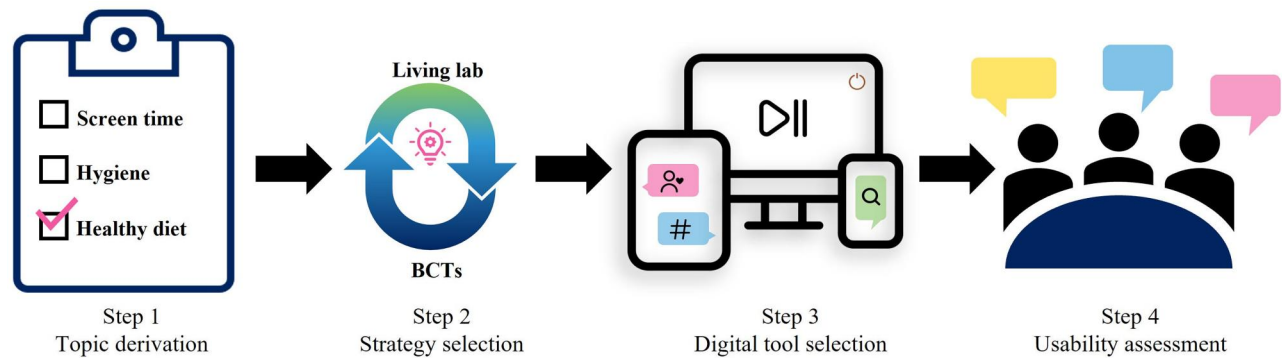


Figure 1. The process of D-LLab development.

digital poster—using cameras and editing apps. In the fourth week, the results of activities were announced and posted on their SNS. Prior to implementation, the intervention plans were reviewed in consultation with a school counsellor to ensure that all interventions were workable. Usability evaluation was conducted immediately after the intervention.

Data collection

All data were collected after obtaining consent from both adolescents and their parents. The brief pre-intervention survey was administered to gather participants' demographic information. After the 4-week intervention, a post-intervention survey conducted to assess usability. During the intervention period, participants were required to write weekly reflections immediately after each session.

Data analysis

Quantitative data were analysed using descriptive statistics. Usability outcomes included item-level and total SUS scores (range, mean $\pm$ SD), the intervention-completion rate ($n/N \times 100\%$), and the mean score of single-item satisfaction rating (mean $\pm$ SD).

Qualitative data were analysed with a descriptive content analysis approach. Two researchers (J.L. and H.L.) independently grouped similar comments into broad categories and any coding discrepancies were resolved through team consensus.

Ethics

Ethical approval for this study was granted by the relevant Institutional Review Board [IRB-4-2021-1695]. Since the participants were adolescents, written informed consent was secured from both the participants and their legal guardians before the study began. The researcher collected the contact information of the participants' parents or legal guardians from the signed consent forms and subsequently reached out to them directly to explain the study and request their written consent.

Results

A total of 21 male students (ages 14–16 years) participated in this programme, including nine each from first and second grade and three from third grade. About 95.2% of participants ($n=20$) completed all four sessions and the post-intervention survey. One participant withdrew due to loss of contact during the intervention.

The mean SUS score was 70.75 ± 15.78 (range 47.5–100.0), with 11 participants (55.0%) achieving scores ≥ 70 —the established threshold for acceptable usability [23] (Table 1, Supplementary Fig. S1).

Qualitative feedback from the weekly reflections supported the quantitative findings and highlighted the engaging nature of the

Table 1. System usability scale score for each item ($N=20$)

Items	Min	Max	Mean $\pm$ SD
1. I think that I would like to use these Apps frequently	2.0	5.0	3.40 $\pm$ 0.94
2. I found the Apps unnecessarily complex	1.0	4.0	1.95 $\pm$ 0.94
3. I thought the Apps were easy to use	3.0	5.0	4.25 $\pm$ 0.64
4. I think that I would need the support of a technical person to be able to use these Apps	1.0	4.0	1.95 $\pm$ 1.10
5. I found the various functions in these Apps were well integrated	3.0	5.0	3.95 $\pm$ 0.75
6. I thought there was too much inconsistency in these Apps	1.0	4.0	2.20 $\pm$ 1.06
7. I would imagine that most people would learn to use these Apps very quickly	3.0	5.0	4.15 $\pm$ 0.67
8. I found the Apps very cumbersome to use	1.0	4.0	2.10 $\pm$ 1.02
9. I felt very confident using the Apps	3.0	5.0	4.00 $\pm$ 0.92
10. I needed to learn a lot of things before I could get with these Apps	1.0	5.0	3.25 $\pm$ 1.29
Total score ^a	47.5	100.0	70.75 $\pm$ 15.78

a: The total score was calculated according to the formula provided by the original instrument, and even-numbered items were reverse-coded.

digital-based activities. As one illustrative case (Table 2), the intervention followed four distinct stages. First, participants recognized a lack of awareness about how food choices affect their health, which led to the identification of dietary issues. In the second stage, they explored potential solutions, emphasizing the need for education at school, guidance at home, and policy-level support through visible nutrition labelling. Based on this discussion, they co-developed a dietary education initiative named Wise Diet! In the third stage, participants created promotional materials, such as healthy eating videos and educational content. Finally, during the fourth stage, they shared these outputs through the school's social networking platform (Fig. 2).

In addition, the digital artworks created by participants each week supported these positive usability results, further illustrating their active engagement with the D-LLab. In the problem identification phase, the causes of dietary problems were different for each group such as absence of parents due to dual-income families, easy access to fast food, taste of vegetables, and lack of knowledge about healthy foods. Based on the solutions explored in the second phase, in the third phase, three groups organized a cooking class and produced online educational materials. One group filmed a promotional video for healthy eating and produced online educational materials. In the

Table 2. Weekly structure of D-LLab: activities, designer intentions, and participant responses

Week	D-LLab stage	Designers' intention	Participants' activity	Activity response (example)
1	Identifying problems	Experiencing difficulties comprising healthy food	Online grocery shopping	They created a meal plan consisting only of foods that appeared to contain a lot of vegetables
2	Exploring solutions	Identifying barriers to comprise healthy food Finding a way to solve the problem	Making 'why-why' chain to explore underlying causes Gallery walk	'Because we don't know how the food affects our bodies, we just eat what we usually eat' 'Teachers should educate about food effects and ingredients; parents should teach nutrition at home; policymakers should post nutrition labels in visible places'
3	Solving problems	Planning how to solve the problem Performing the activities to solve the problem	Brainwriting and activity planning form Performing activity plan	Developing dietary education program 'Wise diet!'
4	Disseminating solutions	Sharing results	Presentation	'Wise diet!' Creating healthy food promotion video and educational material Presenting the material and posting on school's social media channels



Figure 2. An example of D-LLab results.

solution dissemination stage, all the groups shared their results on the school social networking sites (Fig. 2). We observed that the participants explored and utilized other online resources such as YouTube, PowerPoint, and video-editing applications, in addition to the applications provided during their activities.

Participant satisfaction was high, with a mean score of 8.45 out of 10. Half of the participants ($n = 10$, 50.0%) showed their satisfaction at the maximum score of 10, and 85.0% ($n = 17$) scored above the median. Representative open-ended feedback included statements such as, 'This is amazing'; 'Learning something new'; 'The easiest way to stay healthy'; 'A fun programme for adolescents to learn'; 'We are good citizen scientists'; and 'Digital-based Living Lab is an interesting application'. In addition, participants repeatedly emphasized the importance of teamwork and peer collaboration, frequently mentioning words such as 'with friends', 'team activity', 'unity', and 'cooperation'. Although some participants initially reported minor difficulties, such as noise and uneven contributions within groups, they gradually expressed increased motivation to contribute actively, driven by a sense of responsibility towards their teams. Most participants noted that they regularly interacted with friends from different cultural backgrounds in daily life, which facilitated smooth interactions during the D-LLab activities.

Discussion

Major findings

This study evaluated the usability of D-LLab intervention aimed at promoting healthy dietary behaviours among adolescents. Throughout the 4-week intervention, adolescents could leverage digital technologies to discover real-world problems and co-create practical solutions with multiple stakeholders using digital technologies. The D-LLab demonstrated acceptable usability (mean SUS score = 70.75), along with high participant satisfaction and sustained engagement. These outcomes appear to be facilitated by the integration of familiar and interactive digital tools—such as Jamboard and Padlet—which enabled real-time expression, peer collaboration, and creative engagement. Given that adolescents commonly use digital technologies for information exploring, experience sharing, relationship building, and social support [4, 5], such platforms are particularly well-suited to arouse interest and consistent participation in digital health intervention. These tools not only improve access to various health resources but also promote self-exploration and behavioural experimentation aligned with adolescents' intrinsic motivations [27]. As these tools are freely available and compatible with

basic infrastructure such as tablets and Wi-Fi, the intervention demonstrates strong practical transferability across typical school settings and may be readily adapted to other contexts with comparable technological and institutional environments.

Beyond a supportive environment, the success of any cross-setting application also hinges on a clear fit between the target population and the core structure of the intervention [28]. One of the major benefits in this study was the identification and integration of diverse stakeholders to facilitate a Living Lab for adolescents. Notably, native adolescents were included as core stakeholders due to their close social ties with racial and ethnic groups and their capacity to facilitate meaningful collaboration. Previous Korean studies often focused on only racial and ethnic adolescents, which may segregate them, induce prejudice and stigma, and make them feel alienated [21]. To prevent this and increase the Living Lab effect, we recruited native peers and allocated them to each group. The results showed that despite their different cultural backgrounds, the participants got along well and accepted others' opinions.

In line with previous studies highlighting the importance of involving teachers in adolescent-focused Living Labs in school settings [29, 30], this study also engaged the school's counselling teacher as a key stakeholder. The teacher, who was responsible for advising racial and ethnic adolescents, actively participated in the intervention development by reviewing the applicability of D-LLab, encouraged student participation during recruitment, and provided on-site support throughout the intervention. This experience underscores the importance of involving school staff in adolescent participatory intervention, as researchers often have limited insight into students' everyday school experiences and contextual constraints outside the structured intervention setting. In addition, it is further supported by D-LLab's carefully designed structure. Weekly modules, standardized activity sequences, and fixed session length enabled consistent delivery across groups [31]. These features not only supported fidelity within the present setting, but also allow the intervention to be implemented in comparable school contexts without major reconfiguration. Moreover, the participatory design process grounded in Living Lab principles—particularly co-creation, iteration, and inclusiveness—provided the flexibility needed to tailor content while retaining core mechanisms [16].

Although usability scores met the acceptable benchmark, some participants perceived that they needed to learn many things before using the apps, indicating a relatively low efficiency. While the tools used in this study have recently been introduced as useful in educational settings, and orientation sessions were conducted prior to the intervention, they may still have posed a learning burden for adolescents who are unfamiliar with them. In particular, some adolescents had relatively limited experience with digital devices and showed low levels of digital literacy [2], which may reflect their socio-economic background. Therefore, it is important for future digital interventions to consider such disparities and explore user qualitative feedback for improvement [32].

One strategy to mitigate these challenges lies in the strategic deployment of trained facilitators. In line with recommendations from previous Living Lab study [29], our study also trained facilitators to understand the characteristics of adolescents and facilitate the living lab process with minimal interference. This training enabled facilitators to provide timely technical assistance when participants encountered difficulties with digital tools. Furthermore, anticipating facilitators' characteristics and competencies could influence group dynamics; this study tried to minimize competency differences by sharing problem-solving methods after each session. Future research is recommended to include pre-assessments to reflect on their experiences into iterative improvement of facilitation strategies.

Limitations

This study was conducted in a single all-male middle school due to COVID-19 constraints and limited availability of schools

comprising both native and racial and ethnic students. Given that boys often exhibit lower digital literacy than girls [33] and are more influenced by intrinsic motivations (e.g. personal beliefs or enjoyment) in dietary interventions [34], caution should be taken in interpreting the results, given the limitations in their generalizability. Future studies are warranted to adopt more rigorous and context-sensitive methodologies to examine usability across population, environments, and sociocultural domains [28].

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Author contributions

Jisu Lee: Study conception and design, Intervention, Data collection, Data analysis and Interpretation, Drafting of the article, Hyeonkyeong Lee: Study conception and design, Data analysis and Interpretation, Critical revision of the article, Hyeeyeon Lee: Study conception and design, Intervention, Data collection, Data interpretation, Critical revision of the article, Kennedy Diema Konlan: Intervention, Critical revision of the article, Sun Young Shim: Intervention, Critical revision of the article.

Supplementary data

[Supplementary data](#) are available at *EURPUB* online.

Conflict of interest: All authors declare no conflict of interest.

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Data availability

Data used and analysed during the current study is available from the corresponding author on reasonable request.

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Key points

- The study represented that using digital technology in the Living Lab approach helps adolescents take ownership of their own healthy eating habits.
- Youth-friendly content and digital-based activities tailored to their developmental characteristics contributed to increased engagement, usability, and satisfaction.
- With a growing population with diverse sociocultural backgrounds, initiatives that integrate multiple stakeholders to promote healthy eating have been well-received within school settings.

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