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PAPER

The Effectiveness of Using Mobile Learning Application on Undergraduates' Intrinsic Motivation and Their General Nutrition Knowledge

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ABSTRACT

This research aims to investigate the effectiveness of using a mobile learning application on undergraduates' intrinsic motivation and their general nutrition knowledge. This quasi-experimental study involved the participation of 125 students who were divided into two groups: a control group consisting of 62 students and an experimental group comprising 63 students. Pre- and post-intrinsic motivation questionnaires and a nutritional knowledge test were administered. The results showed significant differences between the control group and the experimental group. The experimental group exhibited a higher level of knowledge, and there were no statistically significant differences in intrinsic motivation between the control group and the experimental group. The application was found to be effective in improving nutrition knowledge but did not enhance intrinsic motivation. Further research may be needed to understand the factors that influence intrinsic motivation and how to effectively increase it.

KEYWORDS

mobile applications, online learning, teaching tools, mobile technology, nutritional knowledge, intrinsic motivation

1 INTRODUCTION

In recent years, mobile application (mobile app) technology has become increasingly prevalent in education, offering a convenient and interactive platform for students to access course materials and engage with learning content [1]. Advancements in mobile technology have hastened the growth of online teaching platform. This new teaching approach has gained popularity among students due to its convenience, establishing it as a prominent trend [2]. There has been a rise in the utilization of mobile technology in education [3]. Numerous studies have provided evidence of the effective utilization of mobile technology in augmenting

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and facilitating student learning [4]–[6]. However, it is crucial to acknowledge that mobile technology-based learning cannot completely replace traditional classroom settings or other technology-supported learning approaches [7].

The integration of mobile apps with online nutrition learning has the potential to significantly enhance the motivation and nutrition knowledge (NK) of undergraduate students [8]. By incorporating mobile apps into the nutrition learning experience, educators can create a more engaging and interactive learning environment that may increase students' motivation and retention of NK [9].

Mobile apps can also provide students with access to real-time nutrition information and resources, such as nutrition labels and information about food choices. This can help promote healthy eating habits and improve NK [10]. By providing students with an additional learning platform, mobile app integration may also increase students' motivation and engagement with course materials [11]. This may be particularly beneficial for students who prefer to learn through interactive and multimedia-based resources [12].

There has been an increasing focus on utilizing mobile apps for educational purposes in recent years, with a particular focus on the potential for mobile app integration to improve student motivation and learning outcomes [13]. Several studies have investigated the effects of mobile apps in educational contexts integration on various educational outcomes, including academic achievement, engagement, and retention. These studies have shown that students who used the app had significantly improved NK and reported more positive attitudes towards healthy eating compared to students who did not use the app [14].

However, the effectiveness of integrating mobile apps with online nutrition learning has not yet been fully explored [15]. Numerous studies indicate that mobile apps can effectively enhance nutrition education and boost nutrition knowledge. Sari et al. showed that undergraduate students who incorporated a mobile app into their nutrition course had significantly higher NK scores compared to those who did not use the app [16]. Studies focusing on university students have shown that higher NK is linked to increased consumption of fruits, dairy products, protein, and whole grain foods [17], as well as engagement in other positive dietary behaviors like reading food labels [18].

Several factors can impact the level of NK among university students. This encompasses factors such as their academic field of study, gender, age, and socio-economic status. Several studies have indicated that specific students who receive nutritional education [19] or pursue health-related courses [20] exhibit higher levels of knowledge. Additionally, older students generally demonstrate greater knowledge compared to their younger peers [21], [22], and female students also exhibit greater knowledge [23]. Moreover, high socio-economic status [24], a healthy body mass index [25], and living alone [26] have been positively correlated with higher NK among university students.

Intrinsic motivation (IM) is a type of internal motivation that is driven by personal interests, curiosity, and the inherent enjoyment of an activity or learning experience [27]. When people are intrinsically motivated, they are more likely to seek out new information and resources, be more self-motivated and self-directed in their learning, and be more resilient when faced with challenges [28]. This can lead to a deeper understanding and retention of nutritional knowledge, as well as a greater sense of accomplishment and satisfaction. Additionally, IM has been shown to be a more powerful predictor of long-term learning and performance than external motivators such as grades or rewards [29].

In open and distance learning, motivation plays a crucial role in shaping students' choices regarding what, how, and when they learn [30]. By implementing strategies that boost motivation, students can effectively overcome the challenges and barriers they face during online learning [31]. Studies indicate that students who possess high levels of motivation in learning environments tend to excel in challenging learning scenarios, derive enjoyment from the learning process, actively engage in deep learning, and exhibit determination and creativity [32].

When individuals possess IM, they are inclined to engage in actions for the sheer pleasure or personal challenge they offer, as opposed to being influenced by external stimuli, pressures, or incentives [33]. Although the importance of IM may decline during development, human adults often remain intrinsically motivated to engage in activities [34].

The university experience is a transformative period during which individuals undergo significant changes [35]. Alongside these changes, students' lifestyles may also undergo modifications that can influence their nutritional behaviors. Alterations in dietary habits can have implications not only for the mental and physical well-being of university students but also for their overall health. Therefore, enhancing the NK of university students is crucial for promoting healthier lifestyles [36]–[38].

When students start their university studies, it marks the start of independence and the development of their own lifestyles. This period is critical as existing dietary habits become entrenched or new patterns of behavior are established [39]. Factors such as moving away from the family home, financial instability, a heavier academic workload, time constraints, and limited knowledge about healthy eating principles often result in students adopting eating habits that deviate significantly from a well-balanced diet [40]–[44]. Individuals' awareness of food and their perception of the importance of balanced meals play a significant role in comprehending the health implications of consuming unhealthy foods [45], [46].

The level to which students incorporate their nutritional knowledge into their daily dietary habits has not been adequately clarified. Several studies have indicated that a higher level of knowledge is linked to making healthier food choices [47], [48]. However, there are also studies that have not observed such associations [49].

Given the potential benefits and the widespread use of mobile apps in education, it is important to examine Effectiveness of Using Mobile Learning App on Under-graduates' IM and their General NK. Therefore, more research is required to gain a comprehensive understanding of the elements that influence the efficacy of incorporating mobile apps into education and how these apps increase NK and motivate students towards learning [50]. Mobile apps can be highly effective when created to reinforce educational content, and their widespread availability and affordability have led to a growing interest in mobile learning [51]. By utilizing mobile apps, learning environments can be transformed, and various modes of learning can be employed to enhance student learning [52], [53]. However, the interaction between learners and mobile apps is a complex issue that warrants further exploration [54], [55].

Furthermore, the incorporation of mobile phones into learning equips students with increased flexibility in terms of when, where, and how learning can occur. Consequently, this has implications for educational systems, necessitating adaptations in information technology to meet new demands.

In the era of technology-driven education and an increasing emphasis on lifelong learning, IM holds even greater significance for students. Educational institutions face fewer formalities, increased distractions, and higher time demands.

Consequently, students seeking to stay engaged, as well as educational providers, must increasingly rely on students' IM [55].

This study is unique and the first in Jordan. It incorporates many mobile app-based interventions, such as the capacity to intervene in 'real life' and 'real time', as well as the availability of interaction and the ability to customize interventions according to individual needs. Additionally, it aims to provide effective services and practical interventions to different target groups. Interestingly, no previous studies evaluating the effectiveness of a mobile learning app with online nutritional learning on undergraduate students' motivation and general NK have been conducted among Jordanian university students.

The study on the effectiveness of using a mobile learning app on undergraduates' IM and their general NK holds several potential public health importance as Health Education and Awareness. By exploring the impact of a mobile learning app on undergraduates' nutritional knowledge, the study can contribute to enhancing health education and awareness among young adults. The findings of the study may have implications for academic institutions and curriculum development. If the integration of a mobile learning app proves effective in improving NK and IM, it could provide support for incorporating such tools into educational programs, promoting a more engaging and effective learning experience. The study's findings can contribute to the public health and academic fields by offering insights into the potential impact of a mobile learning app on NK and IM among undergraduates.

1.1 Purpose of study

The purpose of this study is to evaluate the effectiveness of using a mobile learning app with online nutrition learning in terms of its impact on undergraduate students' IM and general NK. The study aims to assess whether the use of mobile learning apps enhances students' IM levels and improves their understanding of and proficiency in general NK.

1.2 Hypotheses of study

Hypothesis 1: Undergraduates who utilize the integrated mobile learning app will experience a significant increase in their IM towards learning compared to those who do not use the app.

Hypothesis 2: Undergraduates who engage with the integrated mobile learning app will demonstrate a higher level of general NK compared to those who do not use the app.

1.3 Strengths of study

1. Standardized Learning Content: Both the control and experimental groups received the same nutritional learning content through automated lectures delivered via the Moodle-v-class platform. This standardization ensures that the knowledge imparted to both groups is consistent, reducing potential confounding factors related to content differences.
2. Long Duration of Intervention: The study included a 12-week (36 hours) intervention period, during which all students attended the automated lectures on

nutrition. The extended duration allows for a more comprehensive understanding of the impact of the intervention on academic IM and nutritional knowledge.

3. Integration of Mobile learning App: The experimental group received additional online training on nutrition applications, specifically using the Calorie Counter by Fat Secret (CCBFS) app. The integration of a popular and well-regarded mobile app enhances the practical relevance of the intervention. The app's features, such as food diary recording, barcode scanning, and personalized coaching, provide students with a convenient and interactive learning experience.
4. Use of Moodle Group Learning Management System (LMS): The study utilized Moodle, a widely used and established learning management system, to conduct the lectures and deliver the educational content. Moodle offers various features and functionalities that support online learning, such as discussion forums, assignment submission, and content management, ensuring a structured and organized learning environment.

1.4 Limitations of study

1. Generalizability: The study's findings may not be generalizable to the broader population beyond the specific sample of undergraduates involved in the study. Factors such as demographics, cultural backgrounds, and educational settings can influence the outcomes. It is important to consider the limitations of the sample and interpret the results within that context.
2. External Factors and Context: The study may not account for external factors or contextual influences that can impact participants' IM and general NK. Factors such as concurrent educational programs, social support, or personal circumstances could affect the outcomes but might not be adequately addressed in the study design. It is important to acknowledge that there are other variables at play that may influence the results and to consider the study findings in light of these potential factors.

2 METHODS AND MATERIALS

2.1 Participants

This study employed a quasi-experimental design utilizing a two-group approach. The participants were the enrolled students in the 'Sports and Health' course during the first semester of the academic year 2022–2023, from October 16, 2022, to January 15, 2023, at a private university in Jordan. The study obtained ethical approval from the scientific research at Al-Ahliyya Amman University (Approval Number: FES-18G-115), and the university administration approved the conduct of this study. All participants provided their informed consent prior to their involvement in the study.

The study included a total of 125 students who were randomly assigned to two distinct groups: the control group, consisting of 62 participants, and the experimental group, consisting of 63 participants. Both groups underwent an approved IM questionnaire and a nutritional knowledge test as a pre-test and post-test. The experimental group participants received one hour of online training focused on nutrition applications. Table 1 displays the characteristics of the participants, providing an overview of their demographic information.

Table 1. Demographic variables about students presented as numbers and percentages of participants in a group

Demographic Variables		Control Group (n% = 62)	Experimental Group (n% = 63)
Sex	Male	35 (55.6)	39 (61.9)
	Female	27 (44.4)	24 (38.1)
Academic year	First year	39 (62.1)	41 (65.1)
	Second year	16 (26.6)	9 (13.5)
	Third year	2 (3.2)	4 (7.1)
	Fourth year	5 (8.1)	9 (14.3)
Cumulative average	Acceptable	4 (5.6)	1 (0.8)
	Good	8 (13.7)	11 (17.5)
	Very Good	21 (33.9)	31 (49.2)
	Excellent	29 (46.8)	20 (32.5)

2.2 Methods

Two instruments were employed for data collection, which were translated from English to Arabic prior to their utilization and reviewed by eight experts in assessment, measurements, Arabic language, and specialized English language from various universities in Jordan. These tools were translated into Arabic because it is the native language in Jordan. This study was conducted by distributing a survey on a pilot sample consisting of 28 university students.

The NK Questionnaire demonstrated strong internal consistency, as indicated by a Cronbach's alpha coefficient of 0.95. Furthermore, specific variables within the questionnaire, such as dietary recommendations, sources of nutrients, choosing everyday foods, and diet-disease relationships, exhibited Cronbach's alpha values of 0.82, 0.93, 0.61, and 0.88, respectively. Similarly, the Internal Motivational Scale (IMS) displayed strong internal consistency, with a Cronbach's alpha coefficient of 0.932. Additionally, the Pearson correlation coefficients between each component of the IMS subscale and the total score were found to be statistically significant ($P < 0.05$). These findings provide evidence for the validity and reliability of both the IMS and NK questionnaire as measurement tools.

The researchers employed a concise NK questionnaire, known as the NK Questionnaire, developed by Parmenter and Wardle [56], to gather data. This questionnaire encompassed four sections, thoroughly evaluating students' comprehension and knowledge of sports nutrition. The sections of the questionnaire encompassed various aspects, including current dietary recommendations, sources of nutrients, everyday food choices, and diet-disease relationships. These four areas constitute the fundamental aspects linking knowledge to dietary behavior, encompassing awareness of recent expert dietary recommendations, knowledge of nutrient-rich foods, the ability to select the healthiest food options, and understanding the health consequences of certain foods. The questionnaire consisted of a total of 45 questions, comprising 34 multiple-choice questions and 11 true or false questions, Test scores ranged from zero to 110.

2.3 Procedure and intervention

In both the control and experimental groups, students were taught nutrition lessons in remote learning mode via Moodle-v-class automated lectures, and measures of IM and NK were applied in both groups. The independent variable in the study was the method of teaching, while the dependent variables were academic IM and NK.

In the experimental group, all participants received a one-hour online training on nutrition applications. The electronic course included automated lectures on nutrition covering various topics related to food, nutrients, health conditions, diet and diseases, nutritional supplements, and calories in nutrients. The lectures were conducted using the Moodle Group Learning Management System (LMS). Additionally, the students in the experimental group used the Calorie Counter by Fat Secret (CCBFS) app to practice and enhance their learning process.

The Calorie Counter by Fat Secret (CCBFS) app was chosen for this study due to its popularity and reputation as a comprehensive tool for tracking nutritional information. The app provides features such as food logging, calorie tracking, and nutritional analysis, which are crucial for promoting awareness and understanding of dietary habits.

During the study, participants were instructed to use the app to track their meals and input the foods they consumed. They were encouraged to use the app regularly, ideally on a daily basis, to track their meals consistently and accurately. Participants were instructed to input all the foods they consumed into the app, regardless of the specific types, to ensure accurate tracking and analysis of their nutritional intake.

The comprehensive database of the app and its ability to input a wide range of food items contribute to its usefulness in tracking and analyzing dietary habits, promoting a better understanding of nutritional choices and behaviors. The app's features, such as personalized coaching and access to a worldwide community, encourage and motivate students to apply what they learn in class anytime and anywhere. The control group received the same nutritional learning content as the intervention group but it was not combined with the mobile app (see Figure 1).

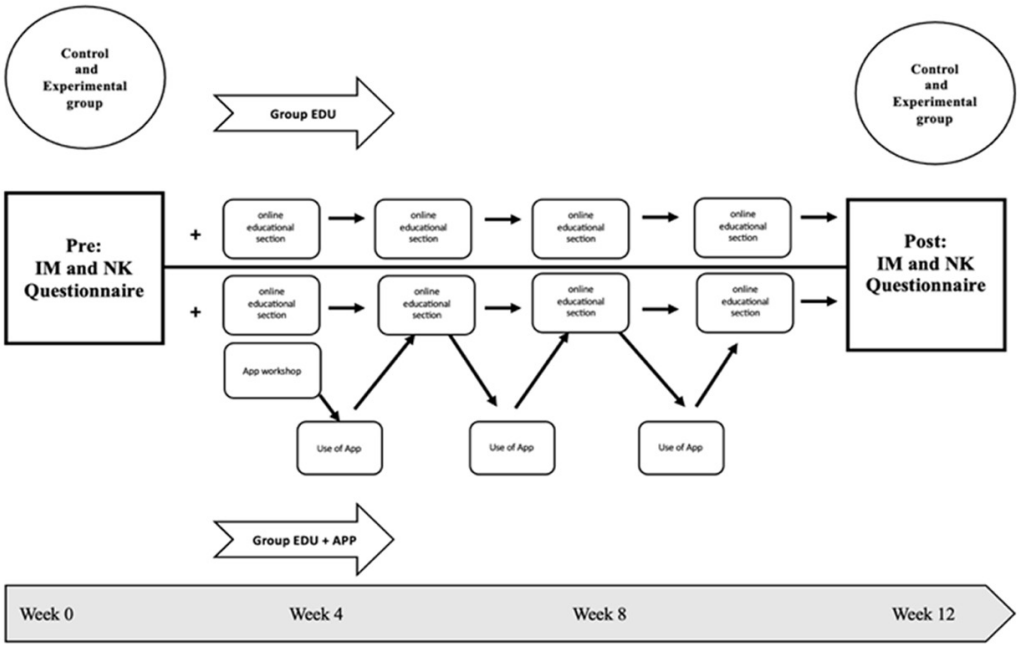

Fig. 1. Procedure and intervention

3 DATA ANALYSIS

In the data analysis phase, the validity and reliability of the study tool for the motivation variable were assessed using measures such as Cronbach's Alpha and the coefficient of self-validity. Categorical data were presented in the form of numbers and percentages. The normality of variable distributions was assessed using the Kolmogorov-Smirnov test. To compare the nutritional knowledge scores and the motivation variable between the control group and the experimental group, one-way ANOVA tests were conducted. All statistical analyses were performed using SPSS version 25.0.

4 FINDINGS & DISCUSSION

4.1 The validity and reliability of variables

Table 2. The validity and reliability of variables

Variables	Number of Items	Cronbach's Alpha	Coefficient of Self-Validity
Intrinsic motivation (IM)	12	0.932	0.965
Knowledge section	–	–	–
Dietary recommendations	4	0.82	0.905
Sources of nutrients	21	0.93	0.964
Choosing everyday foods	10	0.61	0.781
Diet-disease relationships	10	0.88	0.938
Total nutrition knowledge (TNK)	45	0.95	0.974

The variable 'IM' in the questionnaire exhibited a Cronbach's alpha coefficient of 93.2%, indicating strong internal consistency. The subjective validity coefficient was 96.5%, which exceeds the accepted minimum (60%) in social and educational studies, further supporting the validity of the motivation measurement.

The variables within the NK questionnaire displayed Cronbach's alpha coefficients ranging from 0.61 to 0.95. The variable 'total NK' obtained the highest value, indicating strong internal consistency. The values of Cronbach's alpha for the dietary recommendations, sources of nutrients, choosing everyday foods, and diet-disease relationships variables were 0.82, 0.93, 0.61, and 0.88, respectively. All of these values were higher than the accepted minimum (60%) in social and educational studies, providing evidence for the validity and reliability of the NK questionnaire as a measurement tool.

It is worth noting that the Academic Motivation Scale (AMS) used in the study was originally developed by Vallerand et al. in 1992. The IM Scale (IMS) was utilized to assess the level of IM among participants, consisting of eight items divided into two subscales: IM to know and IM to experience stimuli. Participants rated their level of agreement on a 7-point Likert scale, ranging from 1 for 'strongly disagree' to 7 for 'strongly agree'. IM scores fell within the range of 8 to 64. The validity and reliability of the Autonomous Motivation Scale (AMS) have been established through various studies [57]–[59].

4.2 Effectiveness of using mobile learning app with online nutrition learning on undergraduate students' IM and general NK

To test Hypotheses 1 and 2, a comparison was conducted between undergraduates who utilized the integrated mobile learning app and those who did not use the

app in terms of their IM towards learning and general NK. The results indicated the following:

For Hypothesis 1, the statistical analysis revealed that the control group had a p-value of 0.134 ($p > 0.05$) for IM, while the experimental group had a statistical value of 0.149 ($p < 0.05$) for IM. This suggests that the experimental group, which utilized the app, experienced a slight increase in their IM towards learning compared to the control group.

Regarding Hypothesis 2, the statistical analysis revealed that the control group had a statistical value of 0.059 ($p > 0.05$) for the NK score, while the experimental group had a statistical value of 0.119 ($p < 0.05$) for the NK score. These findings indicate that the experimental group, which engaged with the app, demonstrated a higher level of general NK compared to the control group. Additionally, only the control group variable for the nutritional knowledge score followed a normal distribution. It is worth noting that the condition of normal distribution can be dispensed with when sample sizes are greater than 30, as per the central limit theorem (see Table 3).

Table 3. Kolmogorov-Smirnov test for NK scores and IM (95% confidence intervals in parentheses)

Variables	Control Group (n = 62): Statistic (95%CI)	P-value	Experimental Group (n = 63): Statistic (95%CI)	P-value
Nutrition Knowledge (NK)	0.059	0.20	0.119	0.00
Intrinsic Motivation (IM)	0.134	0.00	0.149	0.00

Note: $p > 0.05$ for main effect of group.

The main finding of this study was that the nutritional knowledge of the students who used the application improved significantly, which confirms our second hypothesis. In contrast to our first hypothesis, the use of the mobile app did not improve the students' IM. The results of this study suggest that using a mobile app for nutrition education can have a positive impact on students' NK but may not significantly affect their IM. The statistical analysis showed that there were statistically significant differences in nutritional knowledge between the control group and the experimental group, with the experimental group having a higher level of knowledge.

Table 4. Mean NK scores and IM (95% confidence intervals in parenthesis) between different groups of the questionnaire

Knowledge Section (Max Score)	Control Group (n = 62): Mean (95%CI)		Experimental Group (n = 63): Mean (95%CI)		F	P-value
	S.D	Mean	S.D	Mean		
Dietary recommendations (11)	0.008	7.071	2.606	7.36	2.017	6.57
Sources of nutrients (69)	0.001	12.276	14.960	46.16	8.377	40.77
Choosing everyday foods (10)	0.000	27.189	2.857	6.35	1.885	4.75
Diet-disease relationships (20)	0.087	2.949	4.871	14.48	3.865	13.52
Nutrition Knowledge (NK) (110)	0.000	12.760	23.618	74.345	13.592	65.621
Intrinsic motivation (IM)	0.50	0.456	10.575	48.992	10.769	48.081

Note: $p > 0.05$ for main effect of group.

Table 4 presents the mean NK scores and IM, along with their corresponding 95% confidence intervals, for the different groups in the questionnaire. The statistical values and p-values are provided to determine the significance of the differences between the control group and the experimental group.

For the variable "Dietary recommendations", the experimental group had a statistically significant higher mean score (mean = 7.36, 95% CI = 6.57–8.17) compared to the control group (mean = 7.00, 95% CI = 6.25–7.75), with an F-value of 7.071 and a p-value of 0.008.

In the variable "Sources of nutrients", the experimental group demonstrated a significantly higher mean score (mean = 46.16, 95% CI = 40.77–51.55) compared to the control group (mean = 40.75, 95% CI = 36.38–45.12), with an F-value of 12.276 and a p-value of 0.001.

Similarly, for the variable "Choosing everyday foods", the experimental group showed a significantly higher mean score (mean = 6.35, 95% CI = 4.75–7.95) compared to the control group (mean = 4.75, 95% CI = 3.16–6.34), with an F-value of 27.189 and a p-value of 0.000.

However, for the variables "Diet-disease relationships" and "IM", there were no statistically significant differences between the control group and the experimental group. The F-values for "Diet-disease relationships" and "IM" were 2.949 and 0.45, respectively, with p-values of 0.087 and 0.50.

We can see that there was no statistically significant difference in IM between the control group and the experimental group ($F = 0.45$, $p > 0.05$). This indicates that the use of the integrated mobile app did not lead to a significant increase in IM towards learning.

Table 4 shows a statistically significant difference in NK between the control group and the experimental group ($F = 12.76$, $p < 0.05$). The group that used the integrated mobile app had a higher level of NK compared to those who did not utilize the app, supporting Hypothesis 2.

Therefore, based on the data presented in Table 4, the results support Hypothesis 2, indicating that undergraduates who engage with the integrated mobile app demonstrate a higher level of NK. However, Hypothesis 1 is not supported as there was no significant increase in IM towards learning in the group that utilized the app.

The main finding of this study supports our second hypothesis, as it indicates a significant improvement in the nutritional knowledge of students who used the mobile application. This suggests that engaging with the integrated mobile app positively influenced their NK. Mobile apps have demonstrated their utility as effective tools for promoting nutritional knowledge among undergraduate students [60].

It's worth noting that the literature on nutrition education applications is mixed, with some studies showing positive effects on knowledge improvement, while others do not find significant effects. The use of a nutrition education mobile app was effective in increasing knowledge about nutrition and healthy eating behaviors [61]–[64]. On the other hand, another study did not find significant effects of nutrition education applications on knowledge about nutrition [13]. The contrasting findings suggest that there may be variations in the effectiveness of nutrition apps in different populations or settings [50]. It is important to consider that research findings can differ due to various factors, such as study design, sample size, methodology, and specific characteristics of the participants.

These findings highlight the importance of incorporating technology-based interventions, such as a mobile app, in nutrition education to enhance knowledge acquisition [65]. The mobile app provided students with convenient access to educational

content and interactive features, which likely contributed to their improved nutritional knowledge.

Mobile apps can indeed be valuable tools for promoting nutritional knowledge among undergraduate students [60]. They offer convenience and accessibility. Mobile apps can provide instant access to a wealth of information about nutrition, including food composition, portion sizes, and meal planning tips [66]. They can offer educational resources such as articles, videos, and interactive quizzes to enhance students' understanding of healthy eating.

Based on the study's results, the use of the nutrition education application was effective in increasing students' knowledge about dietary recommendations, sources of nutrients, and choosing everyday foods. However, the app did not have a significant effect on knowledge about diet-disease relationships. To improve future interventions, it is important to consider the following findings.

The finding that the nutrition education application was effective in increasing students' knowledge about dietary recommendations, sources of nutrients, and choosing everyday foods is consistent with the study's hypothesis and aligns with previous research indicating the potential benefits of using technology-based interventions for nutrition education [8], [67].

The significant improvement in knowledge about dietary recommendations suggests that the app provided valuable information and resources to students, enabling them to make informed choices about their dietary habits. This finding indicates that technology can be a useful tool in delivering nutrition education, especially in a digital era where mobile apps are readily accessible [68].

Similarly, the increase in knowledge about sources of nutrients and choosing everyday foods highlights the app's ability to provide practical information on food selection and composition. This result suggests that the app effectively engaged students in learning about the nutritional aspects of their food choices [69], which is crucial for promoting healthy eating behaviors [70].

However, the lack of a significant effect on knowledge about diet-disease relationships is an important finding to consider. It suggests that the app may not have provided sufficient or targeted information in this particular area. Future interventions could benefit from incorporating more specific content on the relationship between diet and various health conditions to improve students' understanding and awareness in this domain.

These findings indicate the potential of nutrition education applications to enhance students' knowledge in certain areas of nutrition. However, further research is needed to optimize the content and delivery methods of such apps, particularly regarding knowledge about diet-disease relationships. By addressing these areas of improvement, future interventions can maximize the effectiveness of nutrition education apps in promoting healthier dietary practices and overall well-being.

However, contrary to our first hypothesis, the use of the mobile app did not lead to a significant improvement in the students' IM towards learning. This result suggests that while the app was effective in enhancing their nutritional knowledge, it did not have a similar impact on their motivation levels. The lack of significant improvement in IM raises the need for further exploration of factors influencing student motivation in the context of mobile app usage.

There are possible reasons for the lack of significant differences in IM between the control group and the experimental group. One possible reason could be the automated nature of the lectures delivered through the mobile app. The limited interaction between teachers/researchers and students may have affected students' motivation, as personal interaction and engagement with instructors can often

positively influence motivation levels [71]. The absence of such interactive elements in the mobile app might have contributed to the lack of significant changes in intrinsic motivation.

It's worth considering that motivation is a complex construct influenced [72] by various factors beyond the use of a mobile app alone. Other factors, such as the overall instructional design [73], individual differences, and teaching approach [74] in students' motivation levels, could also play a role in the outcomes observed.

To enhance IM in future interventions, it may be beneficial to incorporate interactive components or features that promote engagement and interaction between teachers/researchers and students [73]. Additionally, considering the individual differences [75] of the students in the design and implementation of the mobile app could also contribute to a more motivating learning experience.

This result does not align with the research results, which revealed that the utilization of the mobile app enhanced the learning IM of undergraduate students [76]–[78]. It is possible that additional elements could be incorporated into the app to enhance motivation. Future studies could investigate these factors in more detail and explore strategies to enhance the impact of mobile apps on motivation.

This could involve using multiple measurement methods, incorporating a longer intervention period to allow for increased engagement with the app, and expanding the study sample to include a more diverse range of participants. By addressing these considerations, researchers can better evaluate the potential of mobile apps for improving motivation and educational outcomes. Continual investigation and refinement of interventions will contribute to a deeper understanding of how to effectively leverage technology in nutrition education and other educational domains.

In summary, this study found that the use of a nutrition education application was effective in improving students' knowledge about dietary recommendations, sources of nutrients, and choosing everyday foods. The mobile app provided convenient access to educational content and interactive features, contributing to the students' increased nutritional knowledge. However, the app did not have a significant impact on students' IM towards learning. This finding suggests that further exploration and refinement of mobile app interventions are needed to enhance motivation levels.

The contrasting results between the effectiveness of the app on knowledge improvement and IM highlight the complexity of technology-based interventions in education. While mobile apps can be valuable tools for promoting nutritional knowledge, factors such as interactive elements, personalized feedback, and instructional design need to be considered to enhance motivation.

Future research should focus on understanding the factors that influence the effectiveness of nutrition education apps, incorporating behavior theory within the app design, and considering a larger and more diverse sample. It is essential to continually evaluate and refine interventions to optimize the impact of mobile apps in nutrition education and motivation.

5 CONCLUSIONS

The primary objective of this study was to identify the effectiveness of using mobile learning app on the IM among undergraduate students and their NK through online lectures. The results of the study indicated that the mobile learning applications had a positive effect on the NK of undergraduate students in online learning, as it improved within weeks, but there was no positive effect on IM.

By integrating a nutrition-focused mobile app, undergraduates can access nutrition resources, educational materials, and interactive features at their fingertips. This convenience encourages regular engagement and learning opportunities, promoting intrinsic motivation. Personalization and interactivity are key factors in enhancing motivation. Mobile apps can offer personalized experiences tailored to individual users' needs and preferences. By incorporating features such as quizzes, interactive games, goal-setting mechanisms, and progress tracking, the application can engage undergraduates in an interactive and enjoyable learning process. This personalized and interactive approach can boost IM by making the learning experience more meaningful and rewarding. Mobile apps can provide immediate feedback on users' progress and performance. This real-time feedback helps undergraduates track their learning outcomes, identify areas for improvement, and celebrate their successes. Such feedback loops can reinforce IM by instilling a sense of competence and autonomy in the learning process.

Integrating social features in the mobile app, such as discussion forums, virtual communities, or the ability to share achievements with peers, can create a supportive learning environment. The opportunity for social interaction and peer support enhances motivation, as undergraduates can engage in collaborative learning, exchange knowledge, and gain encouragement from their peers. Mobile apps can facilitate continuous learning by providing regular updates, new content, and reminders. By offering a variety of educational resources, such as articles, videos, or meal planning tools, the application can sustain long-term engagement and motivation among undergraduates.

While integrating a mobile app can be effective in enhancing undergraduates' IM and general NK, it's important to note that the design, content, and usability of the application play crucial roles. It should be user-friendly, engaging, and provide accurate and evidence-based information to ensure its effectiveness. Regular evaluation and feedback from users can help refine and improve the application over time.

In conclusion, this study provides evidence that integrating mobile apps with online nutrition learning can be effective for improving NK among undergraduate students, but it doesn't necessarily enhance students' IM towards learning. However, it is important to note that the effectiveness of mobile apps may vary depending on the specific features and content of the app, as well as the individual characteristics of the students using the app, which is recommended to be studied in further research. In conclusion, while integrating mobile apps with online nutrition learning can be effective in improving NK among undergraduate students, more research is needed to enhance our understanding of how to optimize IM through app design, personalization, interactivity, social features, and sustained engagement.

6 RECOMMENDATIONS

Based on the study's findings and conclusions, the following recommendations can be proposed:

Further research should focus on the development and refinement of evidence-based mobile apps for nutrition education. These apps should be designed with user-centered approaches, incorporating engaging features, interactive content, and personalized experiences to enhance IM and improve NK.

Investigate the integration of interactive elements within mobile apps to enhance motivation and engagement. Incorporating elements such as quizzes, challenges, rewards, and progress tracking can make the learning process more enjoyable and stimulating for undergraduate students.

To evaluate the enduring effects and efficacy of mobile apps on NK and IM, it is recommended to conduct longitudinal studies. These studies would involve observing and collecting data over an extended period to assess the long-term impact of mobile apps in these areas. This will provide insights into the sustainability of motivation and learning outcomes over an extended period and help identify any potential decay or fluctuations in motivation levels.

By pursuing these research recommendations, we can advance the understanding and effectiveness of mobile apps in nutrition education, supporting undergraduate students' IM and improving their NK.

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