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Beyond Attendance: Exploring the Impact of Digital Nudges on Engagement Metrics in Online Learning

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Abstract

This study explores the broader impact of digital nudges, specifically WhatsApp reminders, on student engagement in Open Distance Learning environments by integrating attendance and assignment submission data into a composite engagement score. The research addresses a critical gap by examining whether digital nudges influence multi-dimensional engagement, rather than focusing on attendance as a standalone metric. The study involved 79 undergraduate students divided into two (2) groups: a nudged group receiving WhatsApp reminders and a non-nudged group relying solely on standard notifications. Findings reveal that the nudged group achieved higher attendance rates (45.4%) and assignment submission rates (85.71%) compared to the non-nudged group (17.3% and 77.27%, respectively). These differences are practically significant as they indicate that digital nudges can lead to more consistent student participation and timely task completion, critical factors for success in Open Distance Learning environments where engagement is often challenging to maintain. While statistical significance was observed in attendance ($t = 3.558$, $p = 0.0007$), the assignment submission rates did not reach significance ($\chi^2 = 0.91$, $p > 0.05$). The composite engagement score demonstrated a practical trend favouring the nudged group (85.36%) over the non-nudged group (73.64%), suggesting that the combined effect of attendance and assignment submissions provides a more comprehensive measure of student engagement. This trend reinforces the utility of composite metrics, as they capture the interconnected dimensions of engagement, highlighting how even modest improvements in individual behaviours can collectively enhance overall student success in Open Distance Learning environments. These results underscore the practical utility of digital nudges as scalable, cost-effective interventions in Open Distance Learning settings, offering insights into their application for broader engagement strategies and long-term academic success. Future research should explore personalised and longitudinal interventions to refine and validate the effectiveness of digital nudges in diverse educational contexts.

Keywords: assessment submission, attendance, digital nudge, educational technology, engagement, e-tutorial, online learning, Open Distance Learning

1. Introduction

Engagement is a critical determinant of success in online learning environments, encompassing metrics such as attendance, assignment submission, and participation in discussions. However, maintaining engagement in these contexts remains challenging due to the lack of immediate social accountability inherent in traditional face-to-face classrooms. The adoption of Open Distance Learning (ODL), particularly during the COVID-19 pandemic, has further amplified these challenges. The shift to remote learning has underscored the need for innovative strategies to foster meaningful student participation and interaction in the absence of physical classroom settings.

Digital nudges have emerged as a promising solution to this challenge. These subtle, timely reminders or prompts, rooted in behavioural economics and nudge theory (Thaler & Sunstein, 2009), aimed to influence student behaviour without restricting autonomy. Platforms like WhatsApp, known for their immediacy and accessibility, have been effectively used to deliver these nudges. Previous studies have demonstrated that such interventions can significantly enhance specific engagement metrics. For example, Rodríguez et al. (2022) demonstrated that intelligent nudging systems using WhatsApp increased attendance rates significantly (Rodríguez et al., 2022). These findings underscore the scalability and cost-effectiveness of digital nudges as tools for improving student engagement.

Despite this progress, prior research has often focused on attendance as a standalone metric, neglecting the multi-dimensional nature of engagement. Engagement extends beyond attendance to include behaviours such as timely assignment submissions and active participation in discussions, which collectively contribute to academic success. For instance, Kaed et al. (2023) argue that relying solely on attendance metrics risks overlooking critical dimensions of student engagement that are essential for a holistic understanding of learning outcomes. This gap highlights the need for an integrated approach to studying engagement in online learning environments.

This study aims to:

I. Explore the impact of digital nudges on multiple dimensions of student engagement, including attendance and assignment submission rates, in an ODL context;
ii. Evaluate the effectiveness of composite metrics in providing a holistic understanding of student engagement; and
iii. Offer actionable insights for educators to optimise student outcomes by leveraging digital nudges in online learning environments.

By integrating attendance and assignment submission data, this research seeks to validate the efficacy of digital nudges in fostering academic behaviours and provide practical recommendations for enhancing student engagement. The findings contribute to a growing body of knowledge on behavioural interventions in education and address gaps in existing research by employing a multi-dimensional approach to engagement analysis.

2. Literature Review

Digital nudges have emerged as a promising tool in educational contexts, particularly in Open Distance Learning (ODL), where student engagement often presents significant challenges. By leveraging principles from behavioural economics, digital nudges provide subtle prompts to guide learners toward desirable behaviours without undermining their autonomy. Despite their widespread adoption, debates persist regarding their efficacy, ethical implications, and long-term impact. This review explores these discussions, integrating our findings to provide a comprehensive perspective.

2.1. Introduction to Digital Nudges

Digital nudges, subtle behavioural interventions grounded in nudge theory (Thaler & Sunstein, 2009), have gained significant traction in educational contexts. Byrne et al. (2022) emphasised the effectiveness of digital nudges in gamified learning environments, showcasing significant improvements in engagement (Byrne et al., 2022). Brown et al. (2023) assert that strategic nudging based on course analytics successfully enhances engagement in higher education online courses. However, Tate (2023) countered this by emphasising the need for ethical considerations and adaptive digital nudging strategies to address diverse learner profiles effectively (Tate, 2023). This debate underscores the need for future research into personalised nudging strategies tailored to learner profiles.

2.2. Digital Nudges and Attendance

Attendance is frequently cited as a key metric of engagement influenced by nudges. Rodríguez et al. (2022) report significant improvements in attendance rates among students receiving pre-session reminders, attributing this to the routine and accountability established by nudges. Supporting this, Rodríguez et al. (2022) find that periodic reminders reduce absenteeism by prioritising attendance as a key behaviour. However, studies like Bruns et al. (2018) and Matz et al. (2024) suggest that while nudges can be effective, their influence might wane due to habituation, emphasising the need for dynamic designs to maintain their impact (Bruns et al., 2018; Matz et al., 2024). While Anderson et al. (2021) advocate for the simplicity of regular nudges, Bruns et al. (2018) and Weijers et al. (2020) advocate for dynamic strategies that diversify delivery formats and content to sustain novelty and enhance engagement, emphasising the importance of adaptive nudge designs.

2.3. Digital Nudges and Assignment Submissions

The relationship between nudges and assignment submissions also reveals contrasting viewpoints. Lawrence et al. (2019) demonstrated a significant increase in submission rates among nudged students, attributing this to reduced procrastination and better alignment with deadlines. Matz et al. (2024) highlighted that tailored nudges can significantly improve assignment quality by encouraging earlier engagement and better preparation among students. However, Byrne et al. (2022) demonstrated the efficacy of digital nudges in gamified learning environments, showcasing their impact on engagement. Brown et al. (2023) provided evidence of the effectiveness of nudges across various educational settings but note the importance of contextual adaptation. This debate calls for larger, multi-institutional studies to validate findings across diverse educational contexts.

2.4. Broader Dimensions of Engagement

Engagement extends beyond attendance and submissions to include collaborative behaviours and interaction with course materials. Gupta et al. (2024) discussed how digital nudges can enhance collective intelligence in online collaboration. Similarly, Lee et al. (2019) emphasised the importance of multi-dimensional engagement metrics, particularly in e-learning environments, asserting their role in enhancing student success (Lee et al., 2019). Conversely, Harnischmacher et al. (2024) questioned the long-term effectiveness of nudges, noting that while they may prompt immediate behaviours, their influence on sustained engagement remains unclear. This tension between short-term impacts and long-term benefits underscores the need for studies examining how nudges influence holistic academic outcomes over time. Our study's composite engagement scores contribute to this discussion by offering a more integrated perspective on engagement. With practical trends favouring the nudged group, these scores highlight the importance of multi-dimensional measures in capturing nuanced behaviours.

2.5. Platform-Specific Considerations

The choice of platform for delivering nudges introduces further contention. Matz et al. (2024) found that email-based nudges improve assignment outcomes, emphasising tailored delivery (Matz et al., 2024).

Conversely, Yaumi et al. (2023) argued that while WhatsApp has been transformative in teaching and learning, its informal nature could lead to diminished academic seriousness when not carefully integrated into structured learning environments (Yaumi et al., 2023). Brown et al. (2023) advocated for integrating nudges across multiple platforms, suggesting that such diversification accommodates varied student preferences and enhances effectiveness. This debate highlights the importance of comparative studies to determine optimal delivery channels.

2.6. Ethical Implications of Digital Nudges

Lembcke et al. (2019) argued that transparency in digital nudging is vital to address ethical concerns and enhance acceptance of such interventions (Lembcke et al., 2019). Ahmadi et al. (2023), however, argued that transparency and consent mitigate these concerns, advocating for opt-out mechanisms and clear communication about nudge objectives. Michels et al. (2021) emphasised the importance of transparent disclosures to mitigate ethical concerns surrounding personalised nudges (Michels et al., 2021). These contrasting views emphasise the delicate balance between effectiveness and ethical integrity in implementing digital nudges.

2.7. Gaps in the Literature

Despite progress in understanding digital nudges, significant gaps remain. Brown et al. (2024) noted the absence of longitudinal studies on the sustained effects of nudges, a sentiment echoed by Harnischmacher et al. (2024). Yanli and Danni (2021) advocated for personalised nudges and tailored approaches in digital learning environments to better address individual learner needs (Yanli & Danni, 2021). Bergram et al. (2022) emphasised the necessity for exploring digital nudges in diverse contexts, including non-traditional education, to better understand their versatility and adaptability. Addressing these gaps could significantly enhance the theoretical and practical understanding of digital nudges.

This literature reviewed highlights the evolving discourse on digital nudges, emphasising both their potential and limitations in ODL contexts. Our study contributes to this body of work by demonstrating significant improvements in attendance and practical trends in composite engagement scores, despite non-significant assignment submission rates. These findings reinforce the importance of multi-dimensional metrics and personalised approaches in evaluating and designing effective nudge strategies. Future research should focus on longitudinal studies, platform comparisons, and ethical implementations to further the impact of digital nudges on student engagement and learning outcomes.

3. Methodology

This study adopted a quasi-experimental approach to examine the influence of digital nudges on student engagement in an Open and Distance Learning (ODL) environment. Conducted at an ODL higher education institution in Malaysia, this study focuses on key metrics such as attendance and assignment submissions to provide robust empirical evidence for the effectiveness of WhatsApp-based reminders in enhancing student participation. The following sections outline the participants, data collection processes, engagement metrics, analytical approaches, and visualisation strategies employed to meet the study's objectives.

A total of 79 undergraduate students taking an IT course who are enrolled at an ODL higher education institution in Malaysia participated in the study. The students were divided into two groups: 35 participants in the nudged group and 44 in the non-nudged group. The nudged group received WhatsApp reminders prior to scheduled e-tutorials, while the non-nudged group relied solely on standard notifications provided by the Learning Management System (LMS). Although participants came from diverse academic backgrounds, demographic variables such as age, gender, and prior online learning experience were not captured, which represents a limitation of the study. Future research should consider incorporating such data to contextualise findings more comprehensively (Brown et al., 2024).

WhatsApp was selected as the platform for digital nudges due to its ubiquity and widespread usage among Malaysian students. A recent study found that over 95% of students in Malaysia use WhatsApp as their primary communication tool, making it an effective medium for ensuring message delivery and high engagement rates (Suárez-Lantarón et al., 2022). Moreover, WhatsApp enables personalised and timely communication, which aligns with behavioural economics principles that emphasise the importance of context and timing in shaping human behaviour (Cohen et al., 2018). The platform's accessibility, cost-effectiveness, and ability to deliver real-time notifications further reinforce its suitability for this intervention.

Attendance data were tracked across eight e-tutorial sessions using the LMS. The system recorded log-in times and session durations for all participants. Assignment submission data were obtained from the course's centralised submission portal, documenting the number and timing of submissions relative to deadlines. Composite engagement scores were calculated by combining attendance rates (the percentage of sessions attended) and assignment submission rates (the percentage of completed submissions). Composite engagement scores were utilised as an integrated metric to capture the multi-dimensional nature of student engagement. This approach recognised the interplay between consistent attendance, which reflects active participation, and assignment submissions, which indicate task completion and adherence to academic schedules. By weighting attendance and submission rates equally, the composite metric ensured balanced consideration of these critical facets of engagement.

Unlike individual metrics, which may provide a narrow view, composite engagement scores integrate multiple dimensions to capture a holistic picture of student behaviour. For example, attendance alone may reflect participation but not academic progress, while submission rates might show task completion without indicating consistent engagement. By combining these measures, the composite metric aligns with contemporary models that emphasise the critical interplay of diverse engagement dimensions (Berman & Artino, 2018). This holistic approach enables educators to identify nuanced patterns in engagement and target specific student needs effectively.

The use of composite engagement scores aligns with emerging research advocating for more integrated and holistic evaluation models in online learning (Dumford & Miller, 2018). Single metrics often fail to account for the dynamic interactions between various behaviours, potentially overlooking important insights into student participation. The composite score addresses this limitation by integrating multiple dimensions of engagement into a single, actionable measure.

From a practical perspective, composite engagement scores facilitate targeted interventions. For instance, students exhibiting high attendance but low submission rates may require additional support in time management, while those with low attendance but high submission rates might face external barriers to participation. Future studies could refine this approach by exploring alternative weighting schemes or incorporating additional dimensions of engagement, such as forum participation or self-reported study hours (Chong & Wong, 2019).

To evaluate the effectiveness of digital nudges, a series of statistical tests were conducted. A t-test compared composite engagement scores between the nudged and non-nudged groups. Assumptions of normality and homogeneity of variances were verified prior to analysis. For cases where these assumptions were not met, adjustments such as the Welch t-test were applied. To assess differences in assignment submission rates, a chi-square test for proportions was used.

Additionally, a regularised logistic regression analysis was performed to examine the combined effects of attendance rates and group membership (nudged vs. non-nudged) on the likelihood of assignment submission. Logistic regression enabled the study to model complex relationships and identify the relative contributions of independent variables. All analyses were conducted using validated methodologies (Gupta et al., 2024).

Data visualisations were employed to enhance the interpretability of results. Bar charts depicted attendance and assignment submission rates, while scatter plots illustrated relationships between composite engagement scores and other variables. These visual tools provided intuitive insights into trends and disparities across groups. Future studies could extend this approach by incorporating time-series visualisations to track behavioural changes over the intervention period (Rodríguez et al., 2022). The methodological approach adopted in this study provides a structured framework for evaluating the impact of digital nudges on student engagement in ODL contexts. By integrating robust data collection processes and advanced analytical techniques, the study offers valuable insights into the multi-dimensional nature of engagement. The use of WhatsApp as a communication platform demonstrates its effectiveness in leveraging familiar and accessible tools for behavioural interventions. The inclusion of composite engagement scores adds depth to the analysis, offering a comprehensive perspective on student participation. This methodology serves as a foundation for future research exploring the scalability, personalisation, and longitudinal effects of digital nudges in diverse educational settings.

4. Findings and Discussion

4.1. Attendance Rates

Attendance rates among students receiving digital nudges through WhatsApp reminders were significantly higher than those in the non-nudged group. Specifically, the mean attendance rate for the nudged group was 45.4% (SD = 0.375), compared to 17.3% (SD = 0.310) for the non-nudged group. A t-test revealed a statistically significant difference ($t = 3.558$, $p = 0.0007$), underscoring the effectiveness of digital nudges in increasing attendance for e-tutorials. These results align with prior research indicating that reminders can foster habit formation and enhance participation in academic activities (Brown et al., 2024). While the variability in attendance rates was slightly higher in the nudged group, these results underscore the potential for tailored strategies to address different motivational factors across students.

4.2. Assignment Submission Rates

The assignment submission rate was higher in the nudged group as shown in Figure 1 below, with 85.71% of students submitting assignments compared to 77.27% in the non-nudged group. While the chi-square test for proportions ($\chi^2 = 0.91$, $p > 0.05$) indicated that this difference did not reach statistical significance, the positive trend remains notable. This outcome highlights the complexity of behavioural interventions, which may depend on additional factors such as intrinsic motivation, prior academic preparation, or external circumstances. Recent studies have documented similar findings, where the efficacy of digital nudges is often influenced by students' behavioural patterns, external support systems, and access to resources (Deci & Ryan, 2017). Despite the lack of statistical significance, these results support the value of integrating nudges into a multi-faceted engagement strategy (Brown et al., 2024).

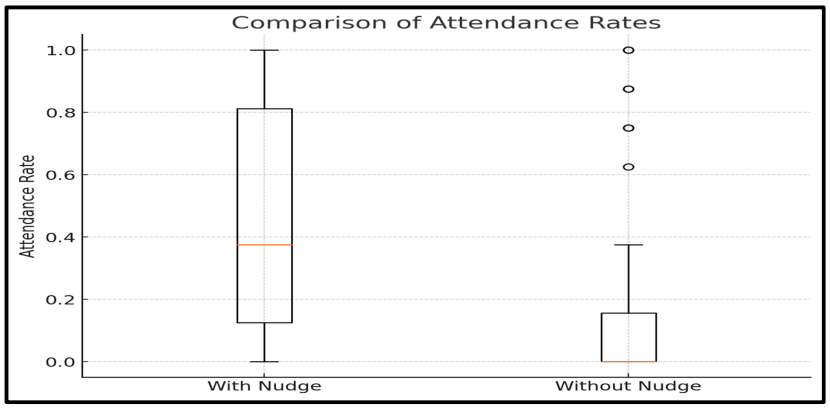

Figure 1. Comparison of Attendance Rates

4.3. Composite Engagement Scores

To provide a holistic measure of student behaviour, a composite engagement score was calculated by combining attendance and assignment submission rates as depicted in Figure 2 below. The nudged group achieved an average composite engagement score of 85.36%, compared to 73.64% for the non-nudged group. While the t-test for these scores revealed a positive trend without statistical significance, the findings emphasise the practical implications of digital nudges in fostering overall engagement (Kaed et al., 2023). Rajabalee and Santally (2019) highlighted the value of combining behavioural interventions with other support mechanisms. The alignment between attendance and assignment submissions further emphasises the interconnected nature of these behaviours, as noted in recent literature.

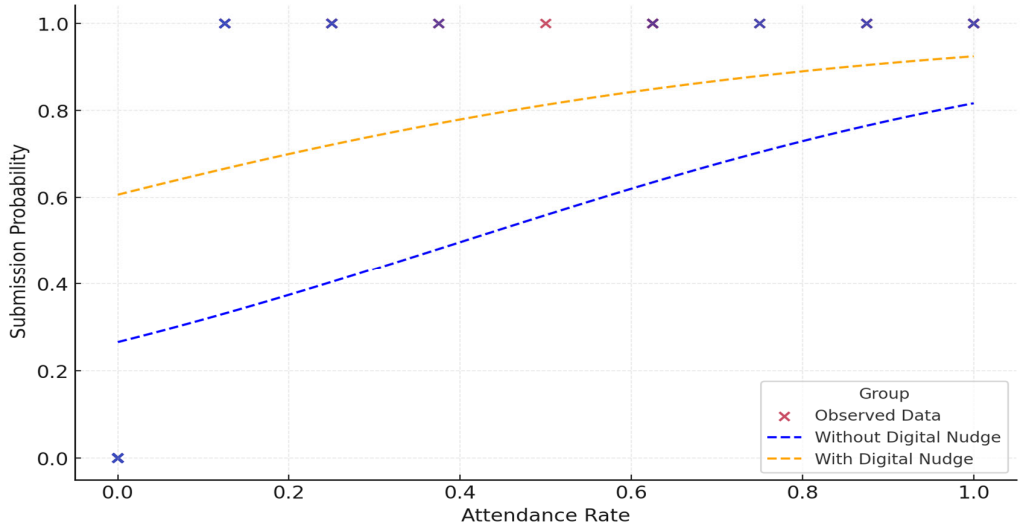

Figure 2. Logistic Regression between Attendance Rate and Submission Probability

4.4. Logistic Regression Analysis

To deepen the analysis, a regularised logistic regression model was applied to assess the combined effects of attendance rates and digital nudges on assignment submissions. The binary outcome modelled was whether students submitted their assignments (1 = submitted, 0 = not submitted), with predictors including attendance rates and group membership (nudged or non-nudged).

The analysis revealed that the attendance rate was a significant predictor, with a coefficient of 3.023, indicating that higher attendance substantially increased the likelihood of assignment submission. Group membership (digital nudge) had a positive effect, with a coefficient of 0.410, showing that students in the nudged group were more likely to submit assignments, even after accounting for attendance rates. Pratiwi and Priyana (2023) demonstrated high accuracy (93.67%) in predicting submission behaviour, reinforcing the effectiveness of attendance and digital nudges as combined predictors. These findings suggest that while nudges positively impact engagement, their effects are magnified when paired with other contributing factors such as attendance.

Scatter plot analyses provided further insights, illustrating the relationship between attendance and assignment submission. Students in the nudged group demonstrated higher submission rates even at lower attendance levels, as evidenced by the clustering of orange data points at submission status = 1. In contrast, the blue data points (non-nudged group) were more dispersed, indicating weaker consistency between attendance and submissions. These visual trends highlight the broader influence of nudges in fostering engagement across diverse attendance levels.

4.5. Implications for Practice

The findings underscore the practical value of digital nudges, such as WhatsApp reminders, in improving student engagement metrics in online learning environments (Brown et al., 2024). The results suggest that while nudges are effective in enhancing attendance and fostering positive trends in assignment submission, their impact may vary based on individual and contextual factors. Incorporating digital nudges into a broader engagement strategy that addresses intrinsic motivation, access to resources, and additional behavioural supports could yield more consistent outcomes (Santoni et al., 2024).

4.6. Broader Implications

This study underscores the potential of digital nudges, such as WhatsApp reminders, to influence multiple aspects of student engagement in online learning environments. By fostering higher attendance and improving assignment submission rates, the findings suggest that digital nudges act as low-cost, scalable interventions capable of driving meaningful behavioural change. While the statistical significance of the difference in submission rates was not established, the practical trends observed in the nudged group highlight the effectiveness of consistent, timely reminders. Nudges appear to work by subtly altering students' behavioural patterns, fostering habits that positively impact their broader engagement with the course.

However, the variability in responses among students highlights the importance of tailoring interventions to individual needs. For instance, students with low attendance but high submission rates may benefit from support that emphasises consistent participation, while those with high attendance but lower submission rates might require assistance with time management and motivation. Future studies should explore these dynamics to refine the design and application of nudges.

The concept of digital nudges aligns with behavioural economics theories, which propose that minor, strategically placed prompts can significantly influence decision-making and behaviour. In the context of education, these interventions may help address some of the challenges posed by the lack of physical interaction and accountability in ODL environments. These findings resonate with studies that underscore attendance as a critical predictor of broader academic engagement and success (Pratiwi & Priyana, 2023).

4.7. The Value of Composite Engagement Metrics

The integration of attendance and assignment submission rates into a composite engagement score provided a nuanced understanding of student behaviour. By combining these metrics, the study moves beyond traditional single-dimensional assessments of engagement to offer a more holistic evaluation of student involvement. This composite score captures both consistent participation (attendance) and task completion (assignment submission), thereby reflecting a broader spectrum of engagement.

The higher composite engagement score for the nudged group (85.36%) compared to the non-nudged group (73.64%) is significant from a practical perspective, even though it did not reach statistical significance. The composite metric underscores the interplay between different facets of student engagement. For example, students who attended more tutorials likely benefited from regular exposure to course material, which may have enhanced their ability to complete assignments. This interaction suggests that attendance, while not directly affecting assignment submission, can indirectly influence other dimensions of engagement, a finding supported by existing literature (Harnischmacher et al., 2024).

The composite engagement score surpasses single metrics by recognising the interconnected dimensions of engagement. Attendance and assignment submissions, when analysed together, reveal patterns that individual metrics may overlook. For instance, high attendance without submissions could indicate barriers to task completion, while high submissions without attendance might reflect a reliance on

external resources. This integrative approach provides actionable insights for tailoring interventions, ensuring they address both participation and performance (Kaed et al., 2023).

Composite metrics are increasingly recognised as essential tools in educational research, particularly in evaluating online learning environments. By integrating multiple engagement indicators, composite metrics provide a richer and more robust picture of student participation, as they account for interdependencies between behaviours (Caspari-Sadeghi, 2022). For instance, regular attendance may not immediately translate to higher academic performance but often correlates with better preparation and greater familiarity with course content, which subsequently improves assignment quality and submission rates.

Moreover, composite metrics align with a growing emphasis on holistic education, where success is not solely determined by isolated actions but by a combination of sustained efforts. Composite metrics are invaluable in identifying nuanced patterns of engagement, as shown in recent models that aggregate multiple engagement dimensions (Mu et al., 2019). In this study, the composite score demonstrated that nudged students consistently outperformed their non-nudged peers across multiple engagement dimensions, reinforcing the effectiveness of reminders in cultivating a broader engagement framework.

4.8. The Role of Individual Differences

The study also highlights the variability in student responses to digital nudges, as evidenced by the outliers in attendance rates. This variability may stem from individual differences in intrinsic motivation, access to technology, or external pressures. Self-determination theory suggests that factors such as autonomy, competence, and relatedness significantly influence student behaviour. For example, highly motivated students may not require reminders, while others facing external challenges may struggle to respond effectively to nudges (Deci & Ryan, 2017). Leimstädtner et al. (2023) highlight the role of reflective and personalised nudges in addressing diverse learner profiles (Leimstädtner et al., 2023).

4.9. Ethical Considerations

While digital nudges present promising opportunities for enhancing engagement, their implementation raises ethical questions regarding autonomy and consent. Students may perceive nudges as intrusive or manipulative, particularly if they lack the option to opt out or are not informed of the purpose behind the reminders. Transparency in communication, coupled with the inclusion of students in the design of nudge-based interventions, is crucial to ensuring that these strategies are ethical and well-received (Suárez-Lantarón et al., 2022). Research into student perceptions of digital nudges is an essential next step towards balancing their effectiveness against ethical considerations.

4.10. Limitations and Areas for Improvement

The study's findings should be interpreted in light of several limitations. The small sample size may have constrained the statistical power of the analyses, highlighting the need for replication with larger and more diverse cohorts. Additionally, the study focused on short-term behavioural changes, leaving questions about the sustainability of these changes unanswered. Future research should adopt a longitudinal approach to explore whether the benefits of nudges persist over time and across multiple courses (Brown et al., 2022).

4.11. Future Research Directions

i. **Personalisation of nudges:** Tailoring nudges based on individual characteristics, such as engagement levels, learning preferences, or motivational profiles, could significantly enhance their impact (Matz et al., 2024).

ii. **Expanding engagement metrics:** Incorporating additional indicators, such as participation in online discussions, quiz performance, and course completion rates, would provide a more comprehensive view of student engagement (Brown et al., 2022).
iii. **Sustained behavioural change:** Examining the long-term efficacy of digital nudges in fostering engagement across multiple courses or academic terms would provide valuable insights into their durability and impact (Byrne et al., 2022).
iv. **Ethical implementation:** Further research should explore students' perceptions of digital nudges, with a focus on ensuring transparency, consent, and autonomy in their implementation (Akkara et al., 2020)

5. Conclusion

This study contributes to the understanding of digital nudges by examining their impact on student engagement in ODL contexts. By integrating attendance and assignment submission rates into a composite engagement score, the research underscores the effectiveness of WhatsApp-based nudges as a practical and scalable intervention to enhance participation. The findings highlight significant improvements in attendance and practical trends in assignment submissions and composite engagement scores, favouring students who received digital nudges. The results align with prior research suggesting that periodic and personalised reminders can positively influence behavioural patterns in educational settings. Although statistical significance was not achieved for assignment submission rates, the observed trends support the notion that consistent reminders encourage students to prioritise academic tasks, particularly in self-directed ODL environments. These findings reinforce the broader utility of composite metrics, which provide a holistic understanding of engagement by capturing the interplay between attendance and task completion. By leveraging WhatsApp, a familiar and widely accessible platform, this study demonstrates the practical benefits of delivering timely, cost-effective interventions to students. However, the success of nudges depends on addressing individual differences, such as intrinsic motivation and external barriers, to maximise their impact. Future research should explore the personalisation of nudges to meet diverse learner needs and investigate their long-term impacts on academic outcomes. Furthermore, ethical considerations, including transparency and consent, must remain central to the design and implementation of nudging systems to ensure acceptance and trust among students. In conclusion, this study offers valuable insights into the role of digital nudges in enhancing student engagement in ODL settings. The integration of composite engagement scores provides educators with actionable metrics to evaluate and refine interventions, setting the stage for future advancements in online education.

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