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Mobile Phone Usage Patterns in the Classroom among Quantum Courses Analyzed by a Clustering Algorithm

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Abstract: *This study employs a mixed-methods approach to investigate mobile phone usage patterns among quantum science students, integrating survey analysis with K-means clustering to identify distinct behavioral profiles. While mobile phones offer significant educational potential in accessing real-time quantum technology developments, their dual nature as both learning tools and sources of distraction presents critical challenges for academic focus. Our analysis reveals three distinct user clusters: Strategic Users (38%) who demonstrate balanced integration of technology for academic purposes, Distracted Users (42%) characterized by high entertainment usage and attention distraction, and Minimalist Users (20%) who maintain limited device engagement. The clustering results demonstrate significant correlations between usage patterns and academic performance, with Strategic Users achieving the highest learning outcomes. The study further establishes that perceptions of mobile phone utility vary substantially across clusters, explaining the polarization in benefit-risk assessments observed in survey responses. Based on these findings, we propose differentiated intervention strategies tailored to each user profile, moving beyond one-size-fits-all policies to optimize technology integration in quantum science education. This research contributes to educational technology literature by providing empirical evidence for cluster-based approaches to digital device management in specialized STEM disciplines, offering practical frameworks for enhancing classroom engagement while mitigating technological distractions in rapidly evolving fields like quantum science.*

Keywords: *Quantum course; mobile phone usage; classroom behavior; K-means clustering*

1. Introduction

The impact of technology saturation on modern well-being provides essential context for understanding the pervasive role of mobile phones in educational settings [1]. Barr et al. provide a valuable 25-year historical perspective on the integration of technology, particularly smartphones, into classroom environments [2]. Dempsey, O'keefe, and Quan-Haase provide comprehensive literature reviews examining mobile phone usage patterns within university classroom settings [3]. This paper investigates the impact of mobile phone usage on the quantum classes.

1.1. The Duality of Mobile Phones: Class Needs versus Non-Class Needs

The relentless progression of societal development, economic enhancement, and scientific innovation has cemented the mobile phone's status as an indispensable fixture of modern life. Its pervasiveness extends deeply into the educational sphere, particularly among university students, many of whom possess one or even multiple devices. Within the university classroom, the mobile phone has transitioned from a mere communication tool to a dynamic educational resource. When confronted with academic queries or complex concepts, students instinctively turn to their devices for immediate clarification, and a vast majority of these inquiries can be resolved instantaneously. This represents the positive facet of in-class mobile phone usage: fulfilling class needs.

However, a parallel phenomenon exists—the use of mobile phones for purposes entirely unrelated to the ongoing instructional activities. This non-class usage, which includes activities such as social networking, gaming, and video consumption, is remarkably common, underscoring both the universality and high frequency of mobile phone interaction in academic settings. The modern smartphone's capabilities are increasingly comprehensive, offering meticulously targeted applications

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that enrich—and potentially complicate—study, daily life, and entertainment. This expansion of functionality presents students with a continuous stream of choices regarding how to utilize their devices during class time, often pitting academic priorities against compelling distractions.

1.2. Analysis of the Impact of Non-Class Mobile Phone Use on Classroom Efficacy

The implications of using mobile phones for non-academic purposes during class are multifaceted and predominantly negative. While the specific triggers may vary, the consequence is often uniform: the duration of phone use exceeds initial intentions, leading to an unconscious but significant shift of attention away from the instructor and course material. Beland and Murphy's economic analysis demonstrates that technology serves as a significant source of distraction with measurable impacts on student academic performance [4]. The user, engrossed in the immediate gratification of replying to messages, advancing in a game, or watching entertainment videos, becomes oblivious to the knowledge being disseminated in the classroom. McDaniel and Drobot's meta-analytic review demonstrates how the mere presence of smartphones affects learning performance and cognitive load [5].

This attention shift directly precipitates a decline in classroom efficiency. Missed explanations and conceptual foundations create gaps in understanding that are difficult to rectify through subsequent self-study, which lacks the nuanced guidance of a teacher's live exposition. Furthermore, even brief periods of inattention can have cascading effects. A ten-minute lapse may be followed by exercises predicated on the very concepts missed, thereby undermining a student's confidence and patience. Over the long term, habitual reliance on mobile phones for quick answers, rather than critical thinking and problem-solving, can fundamentally alter study habits. Wilmer, Sherman, and Chein provide a comprehensive review exploring the links between mobile technology habits and cognitive functioning [6]. The capacity for deep, sustained thought and independent analytical reasoning may gradually erode, fostering a dependency that compromises intellectual autonomy. Ward et al. demonstrate through experimental research how the mere presence of one's own smartphone reduces available cognitive capacity [7]. The present study on college students' use of mobile phones in the classroom is situated within this context of rapid technological renewal. Bianchi and Phillips identify key psychological predictors that contribute to problematic mobile phone usage patterns among students [8]. As mobile phone performance continues to upgrade, the objective duality of the device as a tool becomes increasingly pronounced. This investigation allows for a more intuitive understanding of the related behaviors, offering a relatively objective view of the timing, methods, and prevalence of mobile phone use among peers. It explores the extent of addictive usage patterns and the self-perceived benefits of the devices. For quantum science students, leveraging mobile phones to track market dynamics is essential. Toledo, Dubreilc, and Bahar outline contemporary approaches to quantum computing education and the challenges and opportunities in this emerging field [9]. Yet, the seductive nature of entertainment features poses a persistent threat to academic focus. Therefore, the critical challenge lies not in dismissing the technology, but in formulating effective guidance, proposing actionable suggestions, and implementing changes that can bolster classroom concentration, diminish distractions, enhance subjective initiative, and improve the effective percentage of knowledge retention and understanding.

2. Questionnaire Design on Quantum Students' Use of Mobile Phones in Class

The design of this questionnaire was informed by common phenomena observed in contemporary educational settings and was developed with reference to existing relevant surveys, ensuring a practical and targeted approach. Pardo-Guevara and Caballero present case study research examining smartphone usage patterns and effects specifically in quantum mechanics courses [10]. As demonstrated in the Figure 1, the questions are structured to align with the actual circumstances of quantum science students. The primary objective of this survey was to quantify the duration of mobile phone usage during class, categorize the types of applications employed, and analyze usage patterns from multiple perspectives. This multi-angled approach was intended to yield a more objective assessment of the overall impact—positive or negative—of mobile phones on the classroom experience. Carrier et al. offer a comparative analysis of multitasking behaviors and technology use across different generations of students [11].

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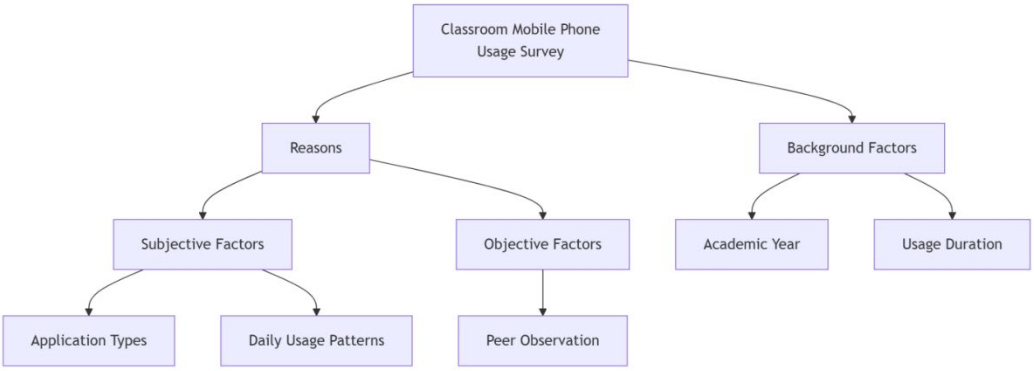

Figure 1: Questionnaire logic.

Acknowledging the potential for survey fatigue among younger respondents, the questionnaire was crafted to be concise and focused. It comprised a set of questions designed to gather data on the basic patterns of classroom mobile phone usage among quantum science students at our institution, capturing their usage intensity, personal attitudes, and cognitive perceptions regarding the device's role in learning.

3. Analysis of Investigation Results

3.1. Demographic Profile of Survey Respondents

Table 1: Distribution of Survey Respondents by Academic Year.

Year	Percentage
Freshman	10.17%
Sophomore	29.66%
Junior	60.17%

As shown in the Table 1, the cohort was predominantly composed of junior-year students (60.17%), followed by sophomores (29.66%), and a smaller number of freshmen (10.17%), according to the above table. This distribution suggests that the responses largely reflect the behaviors and attitudes of students who have experienced a significant portion of their undergraduate curriculum, providing insights into established habits within the major.

3.2. Motivations and Application Usage

The questionnaire provided several answer types to categorize the primary reasons for using mobile phones in class. The data indicate that a substantial portion of usage is driven by legitimate academic needs. This includes fulfilling classroom requirements, facilitating teacher-student interaction, enhancing the diversity and selectivity of communication channels, and ultimately improving the collaborative efficiency of the classroom. McCoy's research documents the prevalence and patterns of digital device use for non-class-related purposes during instruction [12]. It also encompasses self-directed learning and knowledge supplementation aimed at improving the quality of understanding.

However, as shown in the Figure 2, a significant number of students reported using their phones simply to "pass the time." In this fast-developing information age, smartphones host a plethora of applications designed for this very purpose, offering undeniable attraction. As a multiple-choice question, it is understandable that 45.76% of students admitted to using their phones in class to reply to messages, a activity often straddling the line between academic and social communication.

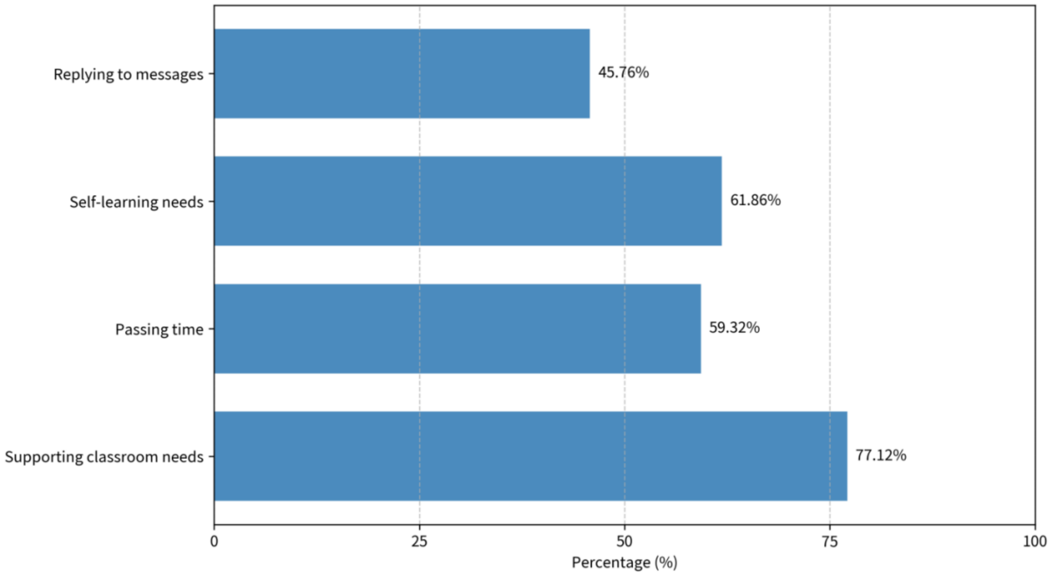

Figure 2: Reasons for Using Mobile Phones during Class.

As shown in the Figure 3, regarding the specific types of applications used, the data from the figures above reveal a clear pattern. Beyond essential schoolwork-type applications (e.g., scientific calculators, programming IDEs, academic databases), video applications are frequently accessed by students during class. A notable minority also reported using game applications, which could involve individual play or even collaborative team-based activities among peers. Applications for news and online shopping accounted for a smaller, yet non-negligible, proportion. The diversity of application usage underscores the rich and varied ways in which students engage with their devices during lectures. It also corroborates the finding that some students use their phones for extended durations, sometimes spanning an entire class period, a phenomenon that warrants further investigation.

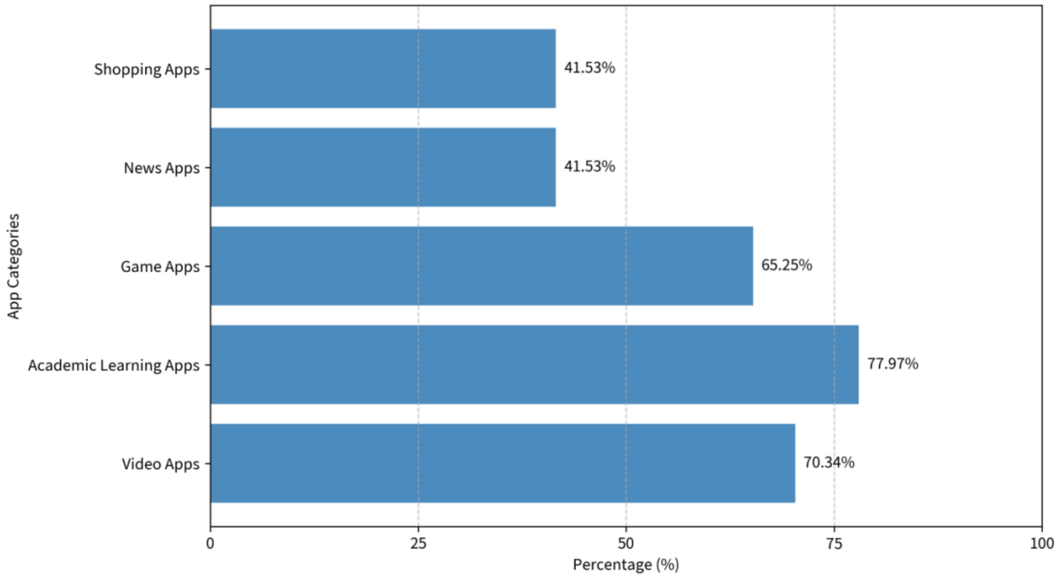

Figure 3: Distribution of App Usage Categories during Class.

This question was included to encourage students to adopt an observational perspective on their peers' behavior. Although the sample size may limit the generalizability of the data, the results offer a rough orientation. They suggest that students most frequently observe their peers using phones for learning assistance. However, observations of students playing games or engaging in other non-academic activities are also common. This multi-choice question was designed to capture the broadest possible range of observable behaviors, and it also identified a small cohort of students who reportedly do not use mobile phones in class at all.

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3.3. Objective Metrics: Duration and Integration of Phone Use

A critical objective metric is the sheer duration of mobile phone use during a standard class period. The results are alarming and quantify the scale of potential distraction.

As shown in Table 2, this question aimed to quantify the general duration of mobile phone usage during a standard class period. The data reveal that the largest group of students (39.83%) use their devices for approximately half of the class. Alarmingly, a substantial minority (27.12%) reported usage lasting "almost the entire class." Felisoni and Godoy's experimental study provides causal evidence linking cell phone usage to academic performance outcomes [13]. This finding raises critical questions about the existence of excessive or addictive usage patterns among this segment and the specific nature of their engagement during instructional time. Panova and Carbonell provide conceptual frameworks for understanding and identifying smartphone addiction behaviors [14].

Table 2: Duration of Mobile Phone Usage during Class.

Option	Percentage
Almost entire class	27.12%
Half of class	39.83%
Occasionally	25.42%
No usage	7.63%

The Figure 4 investigated students' general relationship with their mobile phones in the classroom, as these habits can influence in-class behavior. Prolonged, non-academic phone use after class may lead to fatigue, ingrained distraction, and reduced cognitive readiness for learning. The data show that while many students feel they "cannot live without" their phones, reflecting a deep integration into daily habits, a significant portion report using them primarily "when needed." This distinction is crucial; it differentiates between functional reliance and compulsive usage. The data also indicate that a subset of students primarily uses their phones for entertainment, suggesting that leisure usage may exceed reasonable time allocations. Zhang and Zhang's longitudinal study explicates the cognitive mechanisms underlying smartphone addiction among college students [15].

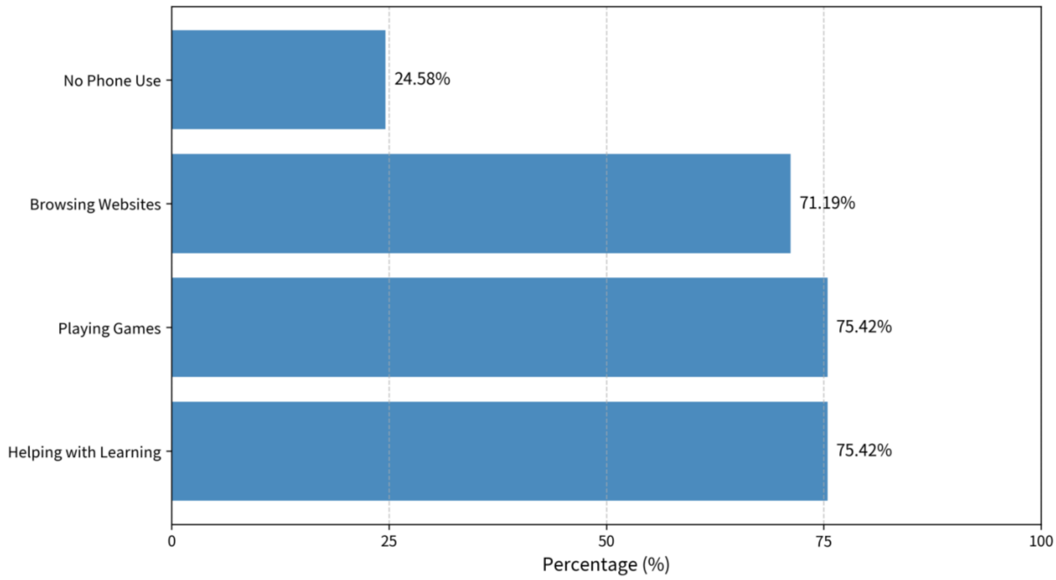

Figure 4: Purposes of Mobile Phone Use in Class.

The Figure 5 is to investigate how quantum students use mobile phones after class, whether they are addicted to mobile phones for too long after class, which leads to the possibility of inattention in class and the low efficiency in class. From the figure, we can find that most students use mobile phones in their daily life, in fact, most of them think that they can't live without the excessive imagination of mobile phones. These findings suggest that mobile phones are deeply integrated into students' daily lives, with many perceiving them as indispensable. The distinction between “using it when needed” and “cannot live without it” may indicate different levels of functional dependence versus habitual attachment. At the same time, more students choose to use it when they need it. Although this option seems to be included in the first option that cannot be separated from the mobile phone, it can also be distinguished whether it is the importance of things that makes you use the mobile phone or when there are other important things, you still cannot leave the mobile phone. From the table, we also find that some students mainly use mobile phones for entertainment, that is, the time spent using mobile phones for entertainment exceeds the normal time spent using mobile phones.

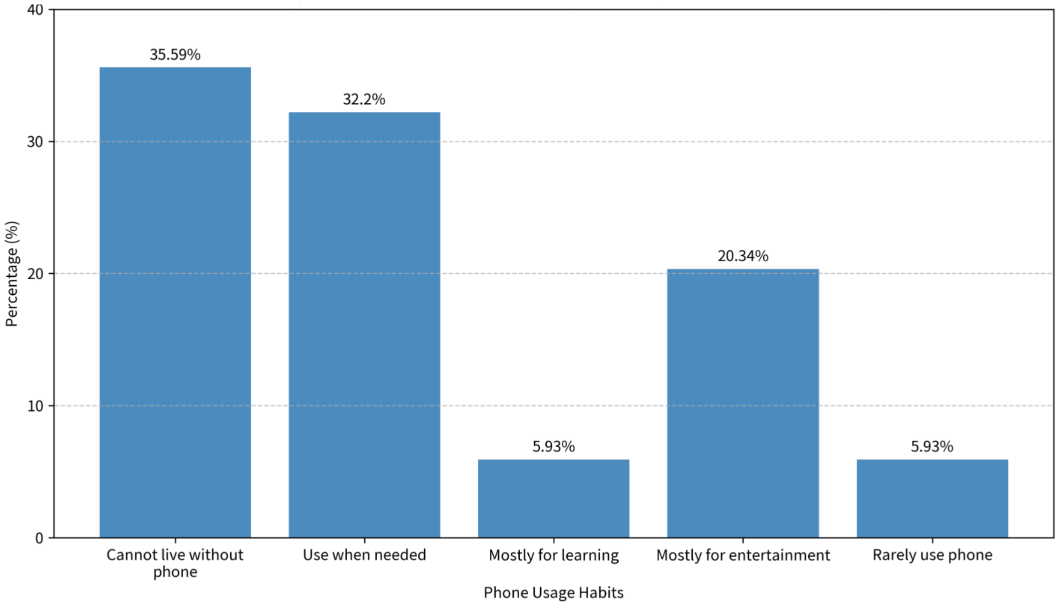

Figure 5: Students' Phone Usage Habits after Class.

3.4. Subjective Perceptions and Attitudes

The subjective perceptions of students regarding the impact of mobile phones are equally important. When asked to weigh the advantages and disadvantages of using mobile phones in class, nearly 70% of respondents believed that the advantages outweighed the disadvantages, according to the Figure 6. Froese et al. identify the significant discrepancy between students' expected learning outcomes and their actual learning when using mobile devices in class [16]. This majority view aligns with the recognized benefits of quick information access and learning support. However, a significant minority of approximately 30% expressed the opinion that the disadvantages were more pronounced, indicating an awareness that the devices are more likely to lead to indulgence and hinder their studies. This internal conflict highlights the complex and personal nature of students' relationships with their devices. Lepp, Barkley, and Karpinski identify correlations between mobile phone usage, anxiety levels, academic performance, and overall life satisfaction [17].

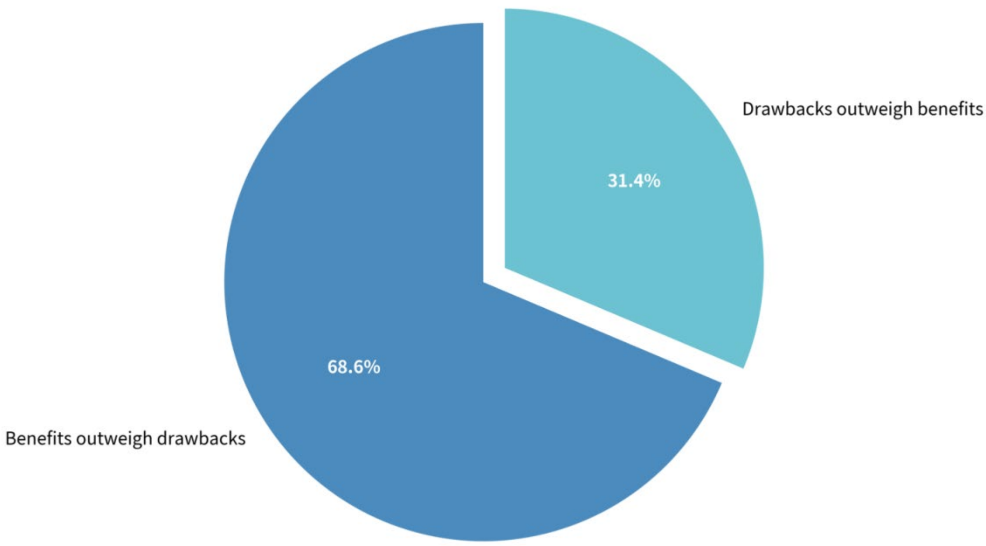

Figure 6: Perceptions of Usage Benefits and Drawbacks.

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3.5. K-means Clustering Analysis of Mobile Phone Usage Patterns

Clustering analysis was employed to identify distinct patterns of mobile phone usage among quantum science students, moving beyond the descriptive statistics presented in previous chapters. This approach allows for a more nuanced understanding of how different student profiles emerge from mobile phone usage behaviors, attitudes, and academic outcomes.

Based on the data, seven key variables were selected for the clustering analysis: daily usage duration, classroom usage frequency, academic application usage, entertainment usage, perceived benefits, attention distraction and academic performance. The above data are normalized using z-score standardization. The elbow method and silhouette analysis were employed to determine the optimal number of clusters k=3 for the K-means algorithm. The Scikit in Python is used to implement this program.

```
phone_usage_kmeans = KMeans(
    n_clusters=3,              # Number of clusters (k)
    init='k-means++',          # Smart initialization
    max_iter=300,              # Maximum iterations
    tol=1e-4,                  # Tolerance for convergence
    random_state=42            # Reproducibility
)
```

The objective function of mobile phone usage is wcss from the Sciket library.

```
phone_usage_wcss = phone_usage_kmeans.inertia_
```

The distance update codes are shown as follows.

```
for i in range(phone_usage_kmeans.n_clusters):
    cluster_points = X[labels == i]
```

The squared Euclidean distance between a phone usage data point $\phi(x_i)$ and a cluster centroid μ_h in the feature space can be computed using the kernel:

$$\|\phi(x_i) - \mu_h\|^2 = K(x_i, x_i) - \frac{2}{n_h} \sum_{\phi(x_j) \in S_h} K(x_i, x_j) + \frac{1}{n_h^2} \sum_{\phi(x_j), \phi(x_m) \in S_h} K(x_j, x_m)$$

where n_h is the number of points in cluster h, and S_h indicates the set of points in cluster h. Then the algorithm minimizes this kernel-based distance.

The K-means algorithm identified three distinct clusters representing different patterns of mobile phone usage among quantum science students.

(1) Strategic users

Moderate daily phone usage of 2-3 hours, over 65% high proportion of academic application usage, strong perception of benefits of 8.2 of rating, lowest attention distraction during classes and highest GPA over 3.6.

(2) Distracted users

High daily phone usage over 5 hours, low academic application usage less than 25%, high entertainment usage around 60%, highest attention distraction during classes and moderate GPA around 3.1.

(3) Minimalist Users

Low daily phone usage less than 1 hour, balanced but limited application usage, neutral perception of benefits, low attention distraction and high GPA over 3.5.

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4. The Dual-Edged Sword: Problems and Proposed Solutions

4.1. Key Problems Identified through the Survey

The survey results unequivocally demonstrate that mobile phones are double-edged swords. Their benefits are substantial. For quantum science students, these devices provide instantaneous solutions to complex problems, thereby accelerating the learning process. They offer diverse pathways to knowledge acquisition, allowing students to find learning tools and explanations that resonate with their individual styles. Critically, they enable students to monitor the rapid evolution of the quantum technology market, ensuring their knowledge remains current and applicable, thus bridging the gap between academic theory and industrial practice. Furthermore, they can enrich classroom interaction, adding a layer of modernity and collaborative potential.

However, the accompanying problems are severe and multifaceted.

(1) Attention Diversion and Cognitive Overload

The primary issue is the effortless diversion of attention. Chen and Seo's meta-analysis establishes a clear relationship between focused attention, smartphone use, and learning effectiveness in educational environments [18]. For students with developing self-discipline, the presence of a phone provides a constant opportunity for distraction. This leads to divided attention between the lecture and the digital world, resulting in cognitive overload and a significant decrease in information retention and learning efficiency. Murphy and Gross quantify the cognitive costs associated with media multitasking and its impact on information retention [19]. The immediate gratification of phone-based activities often trumps the delayed rewards of academic engagement. Rosen, Carrier, and Cheever provide empirical evidence of task-switching behaviors induced by social media and messaging platforms during study sessions [20].

(2) Dependency and Erosion of Critical Thinking

The convenience of mobile phones fosters intellectual dependency. While they provide quick, comprehensive, and accurate answers, they simultaneously discourage the process of deep, critical thinking. Students may increasingly opt for a quick search rather than wrestling with a problem, a process essential for developing robust analytical and problem-solving skills—cornerstones of a quantum science education.

(3) Habituation and Long-Term Cognitive Impact

Prolonged dependency leads to the habituation of poor study habits. Lee et al. examine the relationship between psychological capital, smartphone addiction, and academic burnout among students [21]. A psychological reliance on the device grows, manifesting in behaviors where the phone is perceived as an indispensable extension of the self. This reduction in subjective initiative and self-reliant learning can lead to a gradual decline in inherent thinking ability. It stifles the cultivation of associative and creative thought patterns, which are vital for innovation in a field as conceptual and rapidly advancing as quantum science.

4.2. Proposed Solutions and Recommendations

The goal of this research is not to advocate for the prohibition of mobile phones in classrooms, which is an impractical and conservative approach in the current climate. Instead, the objective is to formulate strategies for guiding their use towards academically productive ends. The following multi-stakeholder recommendations are proposed.

(1) For Educators and Teaching Practitioners

- Enhance Classroom Engagement: Instructors should focus on increasing the intrinsic interest of their lectures. While some students are naturally drawn to complex knowledge, others require more engaging delivery. Teachers can integrate personal anecdotes related to the application of quantum concepts, use physical models or interactive simulations, and employ graphical explanations to make abstract theories more tangible. By improving teaching quality and making the classroom a dynamic environment, educators can effectively compete with the allure of digital distractions.
- Adapt Teaching Methodologies: A shift in pedagogical approach is crucial. Instead of purely lecture-based formats, incorporating active learning strategies—such as think-pair-share

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activities, short in-class problem-solving sessions withoutphones, and project-based learning—can re-center the student's role from passive recipient to active participant. Explicitly designing lessons that intermittently require the use of phones for specific, controlled academic tasks (e.g., polling, accessing a shared simulation, or a quick fact-check) can legitimize and contain their use within a structured framework. Raut and Patil discuss intervention strategies for engaging students in large classrooms, particularly in complex subjects like quantum mechanics.

(2) For Students

- Cultivate Metacognition and Self-Discipline: Students must develop greater awareness of their digital habits and exercise conscious control. This involves setting personal boundaries for phone use during study periods. They can leverage technology itself to this end by using focus-enhancing applications that restrict access to non-academic software during designated class or study times.
- Foster Subjective Initiative: Students should be encouraged to adopt a mindset where the phone is a tool to be wielded intentionally, not a distraction that dictates their behavior. Prioritizing deep work sessions and practicing mindful engagement in class are essential skills for academic and professional success.

(3) For Educational Institutions

- Enrich Campus Life: Universities can play a pivotal role by offering a rich array of extracurricular activities, such as specialized clubs (e.g., a Quantum Computing Club, a Physics Film Society) that intellectually engage students beyond the curriculum. These activities provide meaningful alternatives to screen-based leisure, fostering community and intellectual curiosity while reducing overall dependency on digital entertainment.
- Develop Digital Literacy Programs: Institutions should implement mandatory workshops or modules on digital wellness and effective technology use for academic purposes. Carrier et al. demonstrate the correlation between student digital literacy levels and their academic performance in technology-enhanced learning contexts [11]. Educating students on the cognitive science behind distraction and providing them with practical strategies for managing their digital lives is as important as teaching them academic content.

5. Conclusion

This study has provided a comprehensive examination of mobile phone usage patterns among quantum science students through the novel application of K-means clustering analysis. The research demonstrates that quantum science students exhibit distinct behavioral patterns that can be systematically categorized into three meaningful clusters: Strategic Users, Distracted Users, and Minimalist Users. This clustering approach moves beyond traditional binary classifications of technology use, offering a more nuanced understanding of how mobile devices function within specialized STEM education contexts.

The findings reveal several critical insights. First, the relationship between mobile phone usage and academic performance is not linear but rather mediated by usage patterns and intentionality. Strategic Users, who employ devices primarily for academic purposes, demonstrate that mobile technology can indeed enhance learning outcomes when used purposefully. Second, the clustering analysis explains the apparent contradiction in student perceptions identified in the survey data, revealing that attitudes toward mobile phone utility are closely aligned with actual usage behaviors rather than abstract preferences.

From a theoretical perspective, this research contributes to the educational technology literature by demonstrating the value of person-centered analytical approaches in understanding technology integration. The cluster methodology reveals that the effectiveness of mobile devices in educational settings depends significantly on user behaviors and strategies rather than merely on access or frequency of use. This finding challenges blanket policies regarding technology use in classrooms and supports a more differentiated approach to digital integration.

Practically, the identification of distinct user clusters provides educators and institutions with actionable insights for targeted interventions. Rather than implementing universal policies, educational strategies can be tailored to address the specific needs and challenges of each user group. For Strategic Users, support can focus on advanced academic applications; for Distracted Users, interventions may

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prioritize digital wellness and attention management; for Minimalist Users, approaches can emphasize selective integration of beneficial technologies without pressure toward extensive adoption.

Several limitations should be acknowledged. The study relies on self-reported data, which may be subject to recall and social desirability biases. Additionally, the research was conducted within a specific disciplinary context, and the generalizability of the clusters to other STEM fields requires further investigation. The cross-sectional nature of the data also limits our understanding of how usage patterns evolve over time.

Future research should explore several promising directions. Longitudinal studies could examine how mobile phone usage patterns change throughout students' academic careers and how these changes correlate with evolving learning needs in quantum science. Experimental investigations could test the effectiveness of cluster-specific interventions in improving academic outcomes. Additionally, research could explore how emerging technologies in quantum science education, such as quantum computing simulators accessible via mobile devices, might influence usage patterns and learning effectiveness.

In conclusion, this study demonstrates that the debate surrounding mobile phones in education requires moving beyond simplistic good/bad dichotomies. The cluster-based approach reveals that the educational impact of mobile technology depends fundamentally on how devices are integrated into learning practices rather than whether they are used. For quantum science education—a field characterized by rapid technological advancement and conceptual complexity—this nuanced understanding provides a foundation for developing more effective, personalized approaches to technology integration that can enhance learning while mitigating the risks of distraction. The challenge for educators and institutions is not to resist technological integration but to develop sophisticated strategies that recognize and respond to the diverse ways students engage with digital tools in pursuit of academic excellence.

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