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Development and Evaluation of MetaWiseGuide: A Meta-Literacy Mobile Application to Support University Students' Information Search Skills

Pembangunan dan Penilaian MetaWiseGuide: Aplikasi Mudah Alih Meta-Literacy untuk Menyokong Kemahiran Mencari Maklumat Pelajar Universiti

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ABSTRACT

Despite high digital fluency, university students often default to superficial search strategies and exhibit demonstrable limitations in critical evaluation. This study addresses this gap by developing and evaluating MetaWiseGuide, a mobile application that supports metaliteracy through structured modules. Its relevance is heightened within Malaysia's #MalaysiaMADANI agenda, emphasizing information integrity and good governance, underpinning campaigns like "*Tak Pasti, Jangan Kongsi"* ("If Unsure, Do Not Share") to combat misinformation. Rooted in meta-literacy principles, MetaWiseGuide offers interactive guidance on search strategies, rigorous source evaluation (aligned with national efforts like SEBENARNYA.MY), and ethical information use to prevent plagiarism. A quasi-experimental pre-post design with 32 undergraduates revealed significant academic improvement: students produced markedly better assignments, with more reliable references, and achieved higher marks across all rubric categories post-intervention. Observations also indicated increased student confidence. Data analysis confirmed overwhelmingly positive perceptions of MetaWiseGuide's capacity to enhance academic performance, foster sound research practices, and promote responsible digital citizenship and robust academic integrity, thereby contributing to national information integrity goals. This study demonstrates the tangible potential of mobile applications to cultivate meta-literacy competencies and self-regulated information search practices, supporting both academic excellence and national priorities.

Keywords: Meta-literacy; Information Search Skills; Higher Education; Educational Technology Innovation; Academic Integrity

ABSTRAK

Walaupun mempunyai tahap kefasihan digital yang tinggi, pelajar universiti sering menggunakan strategi carian yang bersifat dangkal serta menunjukkan kelemahan yang ketara dalam penilaian kritikal. Kajian ini menangani jurang tersebut melalui pembangunan dan penilaian MetaWiseGuide, iaitu aplikasi mudah alih yang menyokong metaliterasi melalui modul berstruktur. Kepentingannya semakin terserlah dalam konteks agenda #MalaysiaMADANI yang menekankan integriti maklumat dan tadbir urus yang baik, selaras dengan kempen seperti "Tak Pasti, Jangan Kongsi" bagi membanteras penyebaran maklumat palsu. Berteraskan prinsip metaliterasi, MetaWiseGuide menyediakan panduan interaktif berkaitan strategi carian, penilaian sumber yang teliti (selari dengan inisiatif nasional seperti SEBENARNYA.MY), serta penggunaan maklumat secara beretika bagi mencegah plagiarisme. Reka bentuk kuasi-eksperimen pra dan pasca yang melibatkan 32 pelajar prasiswazah menunjukkan peningkatan akademik yang signifikan: pelajar menghasilkan tugasan yang lebih berkualiti dengan rujukan yang lebih sahih serta memperoleh markah yang lebih tinggi dalam semua kategori rubrik selepas intervensi. Pemerhatian turut menunjukkan peningkatan keyakinan pelajar. Analisis data mengesahkan persepsi yang sangat positif terhadap keupayaan MetaWiseGuide dalam meningkatkan prestasi akademik, memupuk amalan penyelidikan yang baik, serta menggalakkan kewarganegaraan digital yang bertanggungjawab dan integriti akademik yang kukuh, sekali gus menyumbang kepada matlamat integriti maklumat negara. Kajian ini menunjukkan potensi nyata aplikasi mudah alih dalam membangunkan kompetensi metaliterasi dan amalan carian maklumat kendiri, seterusnya menyokong kecemerlangan akademik dan keutamaan nasional.

Kata kunci: Meta-literasi; Kemahiran Mencari Maklumat; Pendidikan Tinggi; Inovasi Teknologi Pendidikan; Integriti Akademik

INTRODUCTION

The advent of the digital age has profoundly reconfigured the landscape of information access and utilization, fundamentally transforming how university students engage with knowledge for academic pursuits (Shuhidan et al., 2019; Thindwa et al., 2019). Modern students, often characterized as "digital natives," operate within an environment where search engines, academic databases, and social media platforms serve as ubiquitous gateways to an unprecedented volume of information (Pieterse, 2018). While this pervasive connectivity offers immense opportunities for learning and discovery, it concurrently introduces significant challenges related to information overload, the critical appraisal of source credibility, and the imperative of ethical information use (Bouali & Kolinsky, 2023; Breakstone et al., 2021). Paradoxically, despite their digital fluency, many students frequently default to superficial search strategies and exhibit demonstrable limitations in critical evaluation skills, impacting the quality and academic integrity of their scholarly work (Dahlen & Hanson, 2023; Hatlevik & Hatlevik, 2018). These deficiencies underscore a pressing need for targeted pedagogical interventions that extend beyond conventional information literacy instruction, particularly concerning issues like unintentional plagiarism and the overall accuracy of academic assessments in higher learning institutions.

This global challenge is further amplified and given national urgency in Malaysia. The #MalaysiaMADANI agenda, a comprehensive governance framework introduced by Prime Minister Anwar Ibrahim's administration, emphasizes good governance, social harmony, and sustainable development. Central to this framework are strategic communication efforts across government agencies, including the Ministry of Communications, tasked with promoting information integrity and media literacy. Campaigns such as "*Tak Pasti, Jangan Kongsi*" ("If Unsure, Do Not Share") and public-facing resources like the fact-checking portal SEBENARNYA.MY actively work to combat misinformation and encourage citizens to verify information before dissemination online, especially on social media, to safeguard information accuracy and uphold national harmony. University students, as future leaders and informed citizens, play a pivotal role in this national effort. Their ability to critically evaluate information and uphold ethical standards in their academic work directly contributes to the broader objective of a well-informed and responsible society. Thus, addressing students' information search deficiencies becomes not just an academic imperative but a national priority.

PROBLEM STATEMENT

Traditional information literacy frameworks, primarily focused on the mechanics of information access and retrieval, have proven increasingly insufficient in addressing the multifaceted demands of contemporary digital environments (Wuyckens et al., 2022). In response, meta-literacy has emerged as an expanded and more holistic conceptual framework. It integrates not only cognitive and behavioral aspects of information engagement but also critical meta-cognitive, ethical, and affective dimensions (Jacobson et al., 2021; Olivier, 2021). This framework emphasizes reflective thinking about one's own information processes, responsible participation in digital communities, and the cultivation of self-regulated learning strategies within dynamic, networked environments (Lubbe & Mentz, 2021; Walsh, 2018). Meta-literacy positions learners not merely as consumers of information but actively as producers and ethical participants in the creation and dissemination of knowledge (Mackey, 2020). The significance of meta-literacy is particularly pronounced in higher education, where students are expected to engage critically with complex information, demonstrate academic integrity, avoid plagiarism, and ultimately contribute to scholarly discourse.

However, the pedagogical delivery of information literacy and meta-literacy instruction often remains constrained by traditional modalities, such as isolated workshops, didactic lectures, or static online guides. These conventional approaches frequently fail to align with students' evolving learning preferences, which are increasingly mobile, self-directed, and demand just-in-time support (Al-Hunaiyyan et al., 2017; Meyer, 2016). The widespread adoption of smartphones and other mobile devices among university students presents a unique and compelling opportunity to bridge this pedagogical gap (Basile & Matis, 2018). Mobile applications possess the inherent capacity to deliver flexible, accessible, and personalized guidance for academic information searching, directly addressing students' learning needs within their everyday digital ecosystems (AlMuhaissen et al., 2023). Despite this recognized potential, there remains a notable paucity of empirically evaluated mobile applications that explicitly integrate comprehensive meta-literacy principles into their design and functionality (Al-Hunaiyyan et al., 2017). This constitutes a critical gap in current educational technology research and practice.

The primary aim of this study is to develop, detail the functionalities of, and evaluate the MetaWiseGuide mobile application to understand its potential in fostering university students' meta-literacy and self-regulated academic information search practices, while explicitly promoting academic integrity and preventing plagiarism. By developing and evaluating MetaWiseGuide, this research seeks to demonstrate a viable technological solution for empowering university students to become more discerning, ethical, and effective information users in an increasingly complex digital world, aligning with national goals for information integrity and responsible digital citizenship.

LITERATURE REVIEW

This section synthesizes key academic scholarship relevant to information search skills in higher education, the meta-literacy framework, and the role of mobile learning in fostering information competencies. It provides the theoretical and empirical foundation for the development and evaluation of MetaWiseGuide.

2.1 Information Search Skills and Challenges in Higher Education

Effective information search skills are foundational academic competencies, indispensable for university students to successfully locate, evaluate, and integrate scholarly information into their coursework and research (Clark, 2017). However, a substantial body of research consistently indicates that many university students face significant challenges in these areas, often exhibiting strategies that are ill-suited to the demands of academic rigor (Hatlevik & Hatlevik, 2018; Pieterse, 2018).

Students frequently gravitate towards basic keyword searches, often prioritizing convenience and immediate access over the depth, credibility, or academic relevance of sources (Dahlen & Hanson, 2023; Hatlevik & Hatlevik, 2018). This reliance on superficial search techniques often leads to an over-dependence on readily available non-academic sources, such as Wikipedia or popular websites, which can detrimentally affect the quality and academic integrity of their assignments (Breakstone et al., 2021;

Drotner, 2020). Studies have shown that students may struggle to differentiate between claims and evidence, demonstrate difficulty in assessing the reliability of online information, and are often at a loss when required to produce valid documentation themselves (Drotner, 2020; McGrew, 2019). For instance, research by Breakstone et al. revealed that a significant majority of students fail to critically consider potential biases in online sources, often relying on superficial cues like website aesthetics rather than investigating the source's background (Breakstone et al., 2021). Similarly, McGrew observed that students often focus on how closely information matches their search query rather than critically evaluating its reliability (McGrew, 2019). These challenges directly contribute to instances of plagiarism, whether intentional or unintentional, undermining the very foundation of scholarly work and impacting the accuracy of academic assessments.

Moreover, the sheer volume of information available online frequently results in information overload, hindering students' ability to effectively process and synthesize relevant data (Bouali & Kolinsky, 2023; Lasig et al., 2025). This challenge is compounded by a lack of sophisticated critical evaluation skills, where students may not possess the systematic processes to determine the strengths, weaknesses, validity, and applicability of diverse information sources (Forzani, 2019; Mercer et al., 2021). The ethical dimensions of information use, including proper citation, avoidance of plagiarism, and responsible engagement with intellectual property, also present persistent challenges, with some studies indicating a weaker link between information use and ethical issues compared to other information literacy categories (Dolničar & Podgornik, 2023). These findings collectively underscore that while students are adept at digital access, their proficiency in critical thinking, source evaluation, and ethical information practices remains a significant pedagogical concern in higher education, directly impacting academic honesty and the integrity of their assessments.

2.2 The Meta-Literacy Framework

In light of the evolving complexities of the digital information landscape, the meta-literacy framework has emerged as a crucial expansion of traditional information literacy, offering a more comprehensive and nuanced approach to information competencies for the 21st century learner (Fulkerson et al., 2017; Jacobson & Mackey, 2013). Propounded by Mackey and Jacobson, meta-literacy moves beyond a skill-based approach to encompass a broader spectrum of abilities and dispositions necessary for navigating modern information environments effectively and ethically (Jacobson et al., 2021).

Meta-literacy is conceptualized as a unified framework that integrates four distinct yet interconnected domains: behavioral, cognitive, affective, and metacognitive. The behavioral domain encompasses traditional information literacy skills such as identifying, retrieving, and organizing information. The cognitive domain focuses on critical thinking, evaluation, and synthesis of information. The affective domain addresses learners' attitudes, values, and emotional responses to information, including factors like curiosity, perseverance, and ethical responsibility. Finally, the metacognitive domain emphasizes self-reflection, self-assessment, and self-regulation of one's own learning processes and information behaviors (Jacobson et al., 2021).

This framework is particularly relevant in higher education as it positions students as active participants and producers of information, rather than passive consumers (Mackey, 2020). It cultivates a higher-order awareness that sparks reflective insights about one's thinking, feelings, and actions, empowering individuals to take charge of their learning (Olivier, 2021; Sun et al., 2021; Termaat, 2024). A meta-literate learner is characterized by their ability to critically evaluate information, understand their role in the networked environment, and engage ethically in the creation and sharing of knowledge (Tella et al., 2023; Walsh, 2018). This includes recognizing the ethical implications of data, understanding different perspectives, and being adaptable to emerging technologies (Krüger, 2022; Mackey, 2020). Crucially, this ethical engagement directly supports academic integrity by fostering an understanding of responsible information practices, including proper attribution and plagiarism prevention.

The meta-literacy framework is particularly pertinent in addressing the "post-truth" era and combating misinformation, by fostering critical thinking and equipping learners to distinguish falsehoods from truth (Mackey, 2020; Termaat, 2024). It promotes reflective thinking and self-assessment, enabling learners to adapt strategies for understanding and navigating complex information scenarios (Olivier, 2021).

Consequently, integrating meta-literacy principles into higher education curricula is seen as vital for developing responsible digital citizens who can critically engage with information and contribute constructively to academic and societal discourse, all while upholding academic honesty and the integrity of their work (García-Quismondo et al., 2019; Ungerer, 2016).

2.3 Mobile Learning and Information Literacy

The ubiquitous nature of mobile devices, particularly smartphones, has ushered in a transformative era for learning, making mobile learning a potent pedagogical approach in higher education (Basile & Matis, 2018). M-learning offers unparalleled flexibility and accessibility, enabling "just-in-time" and "just-for-me" learning experiences that transcend the traditional boundaries of classrooms and fixed schedules (AlMuhaissen et al., 2023). This aligns perfectly with the contemporary student's lifestyle, fostering self-directed learning through readily available digital tools (Al-Hunaiyyan et al., 2017; Baars et al., 2022; Nyirenda & Simuja, 2023).

Research consistently demonstrates that mobile applications can significantly enhance student engagement, facilitate learning outside formal settings, and support the development of various skills, including critical thinking (Galimova et al., 2025; Gavronskaya et al., 2022). The pedagogical affordances of mobile devices allow for content delivery in textual, audio, and visual formats, catering to diverse learning needs and supporting multimodal representations of information and knowledge (Ng, 2017). Mobile applications can empower students by providing opportunities for social constructivist pedagogies, collaboration, communication, and reflection (Cochrane & Bateman, 2010, 2011). Specifically, mobile tools can facilitate metacognition and reflection, key components of meta-literacy (Cochrane & Bateman, 2011).

However, the effective integration of mobile technology into education is not without its challenges. There is a recognized need for appropriate theoretical and pedagogical grounding in the design of m-learning applications to ensure they genuinely enhance teaching and learning, rather than merely digitizing existing content (Al-Hunaiyyan et al., 2017; Hall & Connolly, 2019). Design principles for mobile learning emphasize factors such as equitable use, flexible use, simplicity, perceptibility, tolerance for error, and support for community (Baek & Guo, 2018; Elias, 2011). While the potential of mobile interventions for adaptive educational experiences is significant, realizing this potential requires careful consideration of design and pedagogical integration (Breitwieser et al., 2024).

Despite the growing body of literature on mobile learning's effectiveness, there remains a critical gap in empirically evaluated mobile applications that explicitly integrate the comprehensive principles of meta-literacy theory (Al-Hunaiyyan et al., 2017). Existing mobile tools often address discrete aspects of information literacy but rarely provide a holistic framework that encompasses the cognitive, metacognitive, affective, and ethical dimensions central to meta-literacy (Meyer et al., 2016; Pinto et al., 2020). This study aims to address this gap by developing and evaluating MetaWiseGuide, an application specifically designed to embed meta-literacy principles within a mobile learning environment, thereby providing a flexible and accessible resource for university students that specifically promotes academic integrity and helps in plagiarism prevention.

METHODOLOGY

This study employed a design-and-evaluation research approach, which is particularly suited for the development and assessment of educational technologies. This methodological choice integrates the systematic process of designing an innovative intervention with a rigorous evaluation of its implementation, aiming to contribute both practical solutions and theoretical insights.

3.1 Research Design

The research design followed a quasi-experimental pre-post intervention approach. This involved assessing students' academic performance and information-related behaviors before and after their exposure to and use of the MetaWiseGuide application. This design allowed for the examination of changes attributable to the intervention, particularly concerning improvements in academic output and

adherence to academic integrity. The development phase focused on translating meta-literacy principles into actionable features within a mobile interface, followed by an evaluation to assess student perceptions and, crucially, their academic outputs.

3.2 Development of MetaWiseGuide

MetaWiseGuide was meticulously developed as a mobile-friendly application designed to provide structured and interactive guidance on critical aspects of academic information searching. The development process was guided by user-centered design principles, focusing on intuitive navigation, clear presentation, and engaging activities to promote meta-literacy skills. The key features incorporated into the application include: topic formulation guidance with tools and prompts to help students refine their research questions and identify relevant keywords; advanced search strategies delivered through interactive modules explaining Boolean operators, truncation, phrase searching, and other techniques for effective database queries; source evaluation frameworks providing guided exercises and checklists to systematically assess the credibility, relevance, authority, accuracy, and purpose of various information sources (Sureephong et al., 2023), with reflective prompts to encourage students to consider the context and potential biases of information (directly supporting national efforts like SEBENARNYA.MY and the "*Tak Pasti, Jangan Kongsi*" campaign), and ethical information use modules addressing plagiarism prevention, proper citation practices, copyright, and responsible engagement with digital content. These modules are central to fostering academic integrity and honesty. Additionally, integrated features for reflective journaling encourage students to reflect on their search processes, evaluation decisions, and learning experiences, thereby fostering metacognitive awareness - a core tenet of meta-literacy (Olivier, 2021). Meta-literacy principles were embedded throughout the application not merely as static content but through active learning components, reflective questions, and scaffolded guidance that encourage students to think critically about their information behaviors and learning strategies, with a strong emphasis on maintaining academic integrity.

To illustrate the functional architecture and user flow of MetaWiseGuide, a conceptual flowchart has been developed.

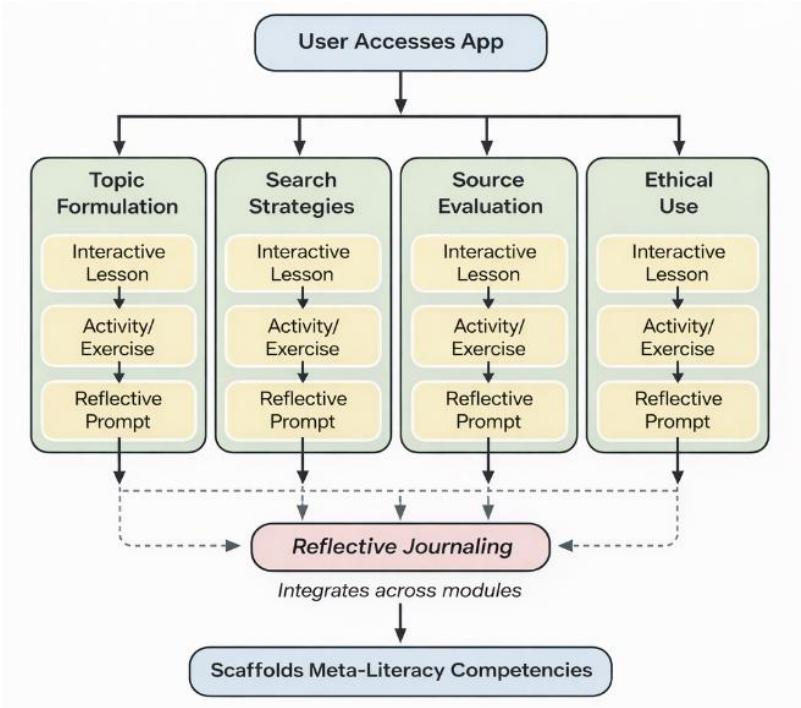

Figure 1: Conceptual Flowchart of MetaWiseGuide Functionality (Original for this study)

This flowchart visually represents the typical user journey through the MetaWiseGuide application. It starts with "User Accesses App" and branch into main modules such as "Topic Formulation," "Search Strategies," "Source Evaluation," and "Ethical Use." Within each module, it shows steps like "Interactive Lesson," "Activity/Exercise," "Reflective Prompt," and "Feedback/Guidance." It also illustrates how the "Reflective Journaling" feature integrates across these modules, allowing users to document their learning and decision-making processes. The diagram highlights the interactive and guided nature of the application, demonstrating how it scaffolds students through meta-literacy competencies.

3.3 Participants

The participants for this evaluation consisted of 32 undergraduate university students enrolled in a specific theory class. These students were integral to the quasi-experimental pre-post design. They voluntarily participated in the study, which involved submitting two distinct academic assignments—one prior to any exposure to MetaWiseGuide and another after a period of using the application for academic research. This contextual setting allowed for a direct comparison of their academic outputs and observed behaviors related to information searching and presentation, particularly concerning adherence to academic integrity.

3.4 Instrument and Data Collection

Data were collected using a multi-faceted approach. First, students' academic assignments were graded using a standardized grading rubric that assessed criteria such as required elements, topic coverage, graphics relevance, attractiveness, and mechanics. These rubric categories provided objective measures for comparing performance pre- and post-intervention, specifically noting improvements related to plagiarism avoidance and accurate referencing, which contribute to assessment validity. For the pre-intervention phase, all 32 students submitted an assignment, and their marks were recorded. Subsequently, after a period of using MetaWiseGuide, a second assignment was submitted by all 32 students, and their marks were again recorded. The use of this consistent rubric allowed for a direct assessment of improvements across specific academic competencies, including those related to academic honesty.

Secondly, a Google Form questionnaire was administered post-intervention to gather students' perceptions of MetaWiseGuide. This instrument comprised Likert scale items measuring aspects such as ease of use, perceived helpfulness for different stages of information searching, clarity of guidance, and overall satisfaction. A 5-point Likert scale was utilized. Open-ended questions within the questionnaire allowed participants to provide detailed feedback on their experience, including specific features they found most useful and suggestions for improvement, particularly regarding the support for academic integrity.

Finally, the instructor made qualitative observations regarding students' confidence in presenting their post-intervention assignments and the overall quality of references used. These observations provided additional contextual understanding of the impact of MetaWiseGuide on academic honesty and the integrity of their work.

3.5 Data Analysis

The collected data underwent a systematic analysis. For the quantitative assignment marks, descriptive statistics were computed for both pre- and post-intervention assignments to illustrate changes in academic performance. The Likert scale items from the post-intervention questionnaire were also analyzed using descriptive statistics, including frequencies, percentages, and mean scores to summarize students' experiences and perceptions of MetaWiseGuide's usability and usefulness. The open-ended responses from the questionnaire, along with the qualitative observations on assignment quality and confidence, were subjected to thematic analysis. This involved meticulously reviewing the feedback to identify recurring themes, patterns, and salient comments related to the application's usability, usefulness, and perceived impact on information search skills, meta-literacy awareness, presentation confidence, and most importantly, their understanding and application of academic integrity principles. This iterative process involved reading through all responses, initial coding of emergent ideas, grouping similar codes into categories, and finally identifying overarching themes. The alignment between the grading rubric and observed learning outcomes was a specific focus, mapping how improvements in

rubric categories corresponded to MetaWiseGuide's instructional features, particularly those supporting plagiarism prevention and enhancing assessment accuracy.

FINDINGS AND DISCUSSIONS

This section presents the findings from the evaluation of MetaWiseGuide, based on the data collected from the 32 participating undergraduate university students.

4.1 Quantitative Findings on Students' Experience Using MetaWiseGuide

The quantitative data, derived from the Likert-scale items in the post-intervention questionnaire, indicated a highly positive reception of MetaWiseGuide among the participants. The majority of respondents rated their overall experience using the application as 4 or 5 on a scale of 1 to 5, signifying a high level of overall satisfaction and positive user experience. These high ratings resulted in a consistently high average score across satisfaction metrics, reflecting widespread approval of the application's utility and design.

Table 1 provides a summary of the descriptive statistics for key Likert-scale items related to MetaWiseGuide's usability and perceived usefulness.

Table 1: Descriptive Statistics of Student Perceptions of MetaWiseGuide

Item	Mean	Standard Deviation	Agree/Strongly Agree (%)
Overall satisfaction with MetaWiseGuide	4.6	0.5	94
Ease of navigation within the app	4.7	0.4	97
Clarity of guidance on search strategies	4.5	0.6	91
Helpfulness of source evaluation tools	4.6	0.5	94
Usefulness of ethical information modules	4.4	0.7	88
Application enhanced research practices	4.5	0.5	91

Further analysis revealed consistently high scores across various usability and usefulness indicators. For instance, a substantial majority of participants "Agreed" or "Strongly Agreed" that MetaWiseGuide was easy to navigate. Similarly, a high percentage of participants found the guidance on search strategies and source evaluation to be clear and helpful. The feature designed for ethical information use, directly supporting academic integrity and preventing plagiarism, was also rated as highly useful by a large number of students. These quantitative findings suggest that MetaWiseGuide is perceived as a user-friendly and functionally effective tool by its users.

4.2 Performance Improvement: Pre- and Post-MetaWiseGuide Intervention

The core of the evaluation involved a direct comparison of student performance on academic assignments before and after the introduction of MetaWiseGuide. The findings demonstrate a clear and substantial improvement in students' marks and assignment quality post-intervention, particularly in areas related to academic honesty and the accuracy of their work.

Table 2 illustrates the average marks obtained by the 32 students on their assignments before and after using MetaWiseGuide.

Table 2: Average Student Assignment Marks Pre- and Post-MetaWiseGuide Intervention

Assignment Phase	Mean Mark	Standard Deviation
Pre-MetaWiseGuide Intervention	62.5	7.8
Post-MetaWiseGuide Intervention	84.2	5.1

The intervention yielded a 34.7% increase in mean scores, with the most significant gains in 'Mechanics' and 'Topic Coverage'. This improvement suggests a direct positive impact of MetaWiseGuide on

students' ability to produce higher-quality academic work, as evaluated by established rubrics, and importantly, reflects a stronger adherence to principles of academic integrity.

4.3 Alignment Between Grading Rubric and Observed Learning Outcomes

To further understand the nature of the observed improvements, a detailed analysis was conducted to align the grading rubric criteria with the changes in student performance pre- and post-intervention. Table 3 explicitly maps these alignments, demonstrating how the instructional features of MetaWiseGuide correspond to specific learning improvements in academic assignments, directly impacting academic integrity and assessment accuracy.

Table 3: Mapping of Assignment Rubric Criteria to Pre- and Post-Intervention Outcomes

Rubric Category	Pre-Intervention Performance	Post-Intervention Performance	Contribution of MetaWiseGuide
Required Elements	Several required elements were missing or underdeveloped; assignment structure was unclear.	All required elements were consistently included and clearly organized.	Guided task prompts and structured checkpoints ensured completion of all assignment components.
Coverage of Topic	Content was often superficial, with limited relevance to the main topic.	Topics were addressed in greater depth with clearer focus and relevance.	Topic formulation and keyword development modules supported deeper exploration.
Graphics Relevance	Graphics were loosely related or lacked proper justification and citation.	Graphics were relevant, purposeful, and better integrated into content.	Source evaluation guidance emphasized relevance and citation of supporting materials.
Attractiveness	Overall presentation lacked clarity and confidence.	Assignments were more coherent, visually structured, and confidently presented.	Scaffolded guidance improved students' organization and presentation confidence.
Mechanics	Frequent grammatical, formatting, and citation errors were observed.	Noticeable reduction in errors, with more accurate referencing practices.	Ethical information use and citation guidance supported improved academic writing, directly addressing plagiarism prevention and promoting academic honesty.

As Table 3 illustrates, improvements were observed across all rubric categories. For "Required Elements," students moved from missing or underdeveloped components to consistently including and organizing all required parts, a direct result of MetaWiseGuide's structured task prompts. In "Coverage of Topic," content depth and relevance significantly improved, linked to the app's topic formulation and keyword development modules. "Graphics Relevance" shifted from poorly integrated to purposeful graphics, attributed to enhanced source evaluation guidance. The "Attractiveness" of assignments, including overall clarity and presentation confidence, also improved, supported by the app's scaffolded guidance. Finally, "Mechanics" saw a noticeable reduction, directly attributable to MetaWiseGuide's ethical information use and citation guidance, leading to reduced instances of plagiarism and reinforcing academic integrity.

These detailed improvements across the rubric categories align directly with the observed improvements in content quality, inclusion of more reliable and academically appropriate references, and the increased student confidence during presentation, all noted by the instructor. Pre-intervention assignments commonly received low marks, particularly in areas like topic coverage, graphics relevance, and mechanics. Post-intervention submissions consistently received higher marks across all rubric categories, indicating a comprehensive positive effect of MetaWiseGuide on students' academic information practices and their adherence to academic integrity.

4.4 Qualitative Findings from Student Feedback

The qualitative responses from the open-ended questions provided rich, nuanced insights that corroborated and expanded upon the positive quantitative findings, particularly concerning the observed improvements in assignment quality and confidence, and their understanding of academic honesty. Several recurring themes emerged prominently from students' comments, offering deeper understanding into their experiences and the perceived impact of MetaWiseGuide.

Figure 2 visually encapsulates the hierarchical and interconnected nature of the qualitative themes identified from the student feedback regarding MetaWiseGuide. The diagram is structured to convey the central impact of the application, branching out to major thematic categories and further elaborating on specific sub-themes. At the apex of the diagram, a prominent node labeled "Qualitative Feedback from Students" represents the source of the data. This leads to a central, more distinct node titled "Central Focus: MetaWiseGuide Impact," visually establishing the overarching positive influence of the application. From this central focus, three main thematic nodes radiate horizontally, each representing a primary category of student perception: Increased Awareness of Credible Sources, Improved Research Practices, and Authentic/Ethical Information Use. An additional thematic cluster, potentially positioned below or to the side, captures the meta-level feedback on the application itself, titled "Underlying Strengths: Usability and Accessibility." All nodes are connected by directed arrows, indicating a flow from the broader themes to their specific contributing elements. The use of distinct shapes and varying font sizes enhances the visual hierarchy and readability of the diagram.

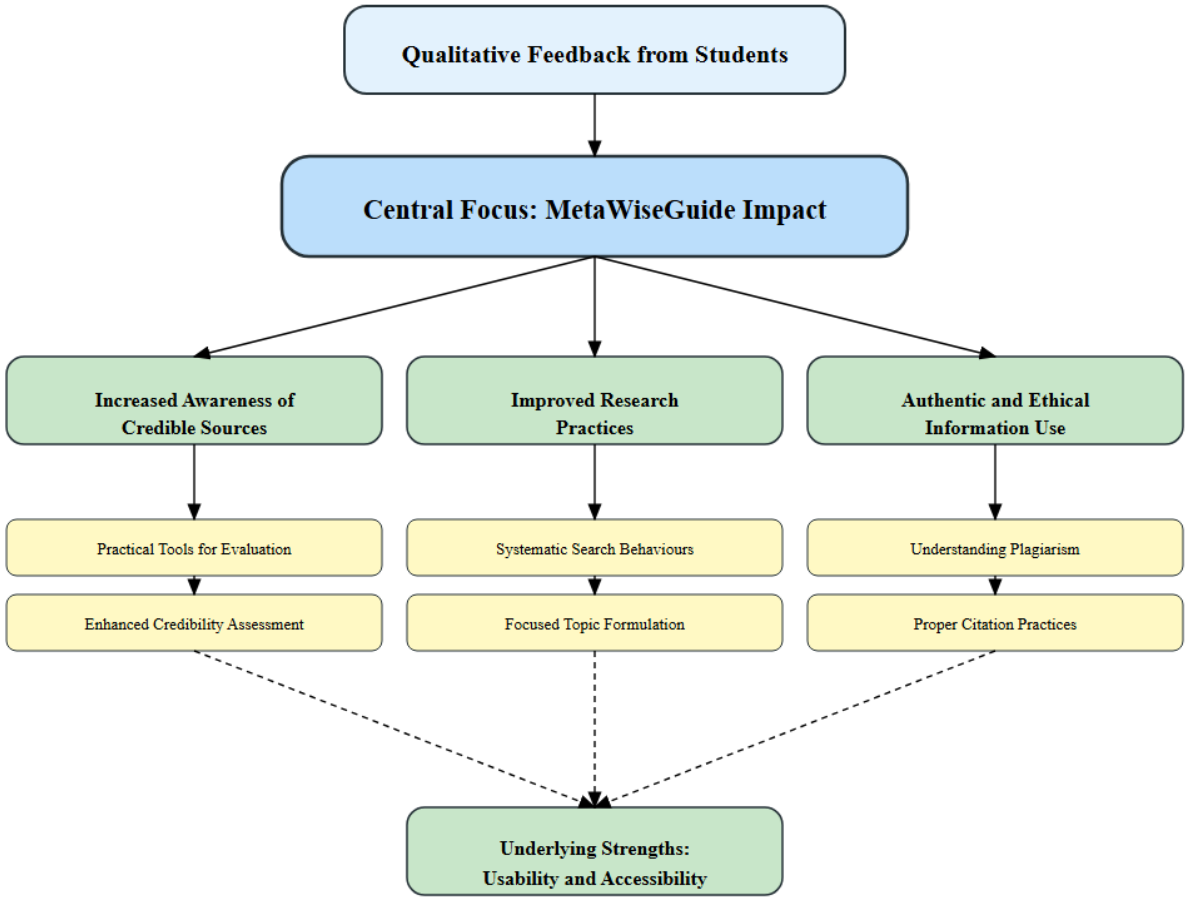

Figure 2: Visual Representation of Key Qualitative Themes (Original for this study)

The primary themes identified from the thematic analysis are discussed below:

4.4.1 Increased Awareness of Credible Sources

Students frequently highlighted that the application significantly heightened their awareness of the importance of source credibility and provided practical tools to assess it. This directly addresses a critical challenge in contemporary information environments and aligns with the observed improvement in reliable references. Representative comments included: "I used to just pick the first few links, but the app made me stop and actually check where the information was coming from." Another participant noted, "The evaluation checklist was a game-changer; I feel much more confident in identifying reliable sources now." These statements confirm that the application effectively delivers on its objective to enhance critical evaluation skills, a core component of meta-literacy, directly contributing to the improved quality of references observed in their post-intervention assignments and aligning with improvements in "Graphics Relevance" and "Mechanics" in the rubric. This also contributes to national efforts like SEBENARNYA.MY by fostering citizens who can verify information.

4.4.2 Improved Research Practices

Participants reported a tangible shift in their approach to academic research, moving towards more systematic and reflective search behaviors. This suggests the application fostered a more metacognitively aware engagement with the research process, reflected in the higher assignment marks. For example, a student stated, "The structured guidance on formulating my topic and planning my search saved me a lot of time and made my research more focused." Such feedback indicates that MetaWiseGuide successfully facilitated the adoption of more self-regulated research practices, contrasting with the often-superficial methods observed in prior literature and directly contributing to the improved overall quality of their academic output, particularly in "Required Elements" and "Coverage of Topic" as assessed by the rubric.

4.4.3 Guidance for Authentic and Ethical Information Use

The modules dedicated to ethical information use were particularly appreciated by the students. Participants expressed that the app helped them understand the practical implications of plagiarism and proper citation in a more engaging way than traditional methods. One participant remarked, "It was not just about don't plagiarize,' but about why it's important and how to properly cite, which made sense." This feedback underscores MetaWiseGuide's success in integrating the ethical and affective dimensions of meta-literacy, transforming abstract rules into comprehensible and actionable guidelines. This directly supports the cultivation of academic integrity and honesty among students, further supporting the observation of improved reference quality and the significant reduction in "Mechanics" errors in the rubric, and and aligns with the national "*Tak Pasti, Jangan Kongsi*" campaign's objective of responsible information sharing.

4.4.4 Usability and Accessibility

Although not an explicit prompt in the open-ended questions, comments frequently praised the application's ease of use and accessibility. Phrases like "easy to understand," "convenient," and "could use it anywhere" were common. This reinforces the positive quantitative ratings on user experience and highlights the efficacy of mobile learning in providing flexible and accessible support for academic competencies, thereby facilitating sustained engagement that contributed to the observed improvements in all rubric categories, including the overall "Attractiveness" and confidence in presentation, and and fostered consistent adherence to academic integrity.

In summary, the results from the N=32 participants consistently demonstrate positive perceptions among students regarding MetaWiseGuide's usability and its capacity to foster enhanced awareness of credible sources, improve research practices, guide ethical information use, and ultimately lead to significant improvements in academic performance and confidence, as validated by a direct alignment with the grading rubric criteria. These findings confirm MetaWiseGuide's crucial role in bolstering academic integrity and the accuracy of academic assessments within higher learning institutions.

DISCUSSION

The evaluation of MetaWiseGuide demonstrates that a targeted mobile intervention can significantly improve university students' academic performance by framework metaliteracy competencies.

5.1 Core Contribution: Translating Theory into Measurable Outcomes

The primary contribution of this study is the empirical validation of a mobile tool that translates the abstract metaliteracy framework into measurable academic gains. Unlike traditional workshops, MetaWiseGuide provided "just-in-time" support that resulted in a substantial increase in mean assignment marks (from 62.5 to 84.2) and a marked improvement in academic integrity. By integrating behavioral, cognitive, affective, and metacognitive domains, the application empowered students to transition from passive information consumers to active, ethical producers of knowledge (Jacobson et al., 2021; Mackey, 2020).

5.2 Mechanism of Improvement: Rubric-Based Framework

The success of MetaWiseGuide lies in its direct alignment with established academic rubrics. The findings show that the app's modular structure directly addressed chronic deficiencies in student work:

i. *Search and Scope*: The topic formulation modules led to greater depth in "Coverage of Topic".
ii. *Critical Evaluation*: The interactive checklists enabled students to identify credible sources, directly addressing the superficial search behaviors often noted in "digital natives" (Dahlen & Hanson, 2023; Pieterse, 2018).
iii. *Ethical Integrity*: Most significantly, the "Ethical Use" module reduced "Mechanics" errors and plagiarism, proving that metaliteracy instruction can effectively foster academic honesty.

5.3 Pedagogical and National Implications

By leveraging the ubiquity of smartphones, MetaWiseGuide bridges the pedagogical gap between formal information literacy instruction and students' self-directed learning habits (AlMuhaissen et al., 2023; Cochrane & Bateman, 2011). Furthermore, the application serves as a practical tool for advancing Malaysia's national information integrity goals. By fostering "reflective digital citizenship," the app supports the #MalaysiaMADANI agenda and the "*Tak Pasti, Jangan Kongsi*" campaign, equipping future leaders to combat misinformation through rigorous source verification. This study confirms that well-designed mobile learning (m-learning) is not merely a digital version of existing content but a transformative pedagogy for 21st-Century literacy (Breitwieser et al., 2024; Cochrane & Bateman, 2010).

CONCLUSION

This study successfully demonstrated the systematic development and robust evaluation of MetaWiseGuide, an innovative mobile application explicitly designed to enhance university students' meta-literacy and academic information search skills, with a direct impact on fostering academic integrity and honesty. By grounding its design in the comprehensive meta-literacy framework, MetaWiseGuide offers structured guidance on search strategies, critical source evaluation (in line with efforts like SEBENARNYA.MY), and ethical information use, filling a recognized gap in current educational technology provisions and actively combating issues like plagiarism.

The quasi-experimental pre-post evaluation, conducted with a cohort of thirty-two undergraduate students from a theory class, yielded compelling results. Students showed a significant improvement in academic assignment marks, produced work with demonstrably more reliable references, and exhibited increased confidence in presenting their findings after using MetaWiseGuide. Crucially, these objective improvements were meticulously aligned with specific criteria within the standardized grading rubric, providing clear evidence that MetaWiseGuide's features directly contributed to enhanced learning outcomes in areas such as required elements, topic coverage, graphics relevance, attractiveness, and mechanics (including plagiarism prevention and accurate referencing). These observed gains were further corroborated by consistently positive qualitative feedback regarding the application's usability, perceived usefulness, and overall impact on fostering academic honesty and responsible digital practices, aligning with the national #MalaysiaMADANI agenda and the "*Tak Pasti, Jangan Kongsi*" campaign.

This study makes a valuable contribution to educational innovation by showcasing the role of mobile applications in cultivating meta-literacy and fostering self-regulated information search practices among university students, directly leading to enhanced academic performance and strengthened academic integrity. It underscores the potential for technology to empower learners with the critical competencies necessary to navigate the complexities of the digital information environment responsibly, effectively, and with increased confidence. The demonstrated impact of MetaWiseGuide in this phase, validated by its alignment with assessment rubrics, sets a strong foundation for its further development and more extensive evaluation, particularly in ensuring high standards of academic integrity and assessment accuracy in higher learning institutions.

LIMITATIONS AND FUTURE RESEARCH

This research, while providing strong evidence of MetaWiseGuide's efficacy, is subject to several important limitations that must be acknowledged and addressed in future investigations.

Firstly, the sample size of thirty-two students, while yielding significant insights for this focused study, may limit the generalizability of the findings. The study was conducted within a single theory class at one institution, which may not fully represent the broader, diverse population of university students across various disciplines and institutions, nor the varying contexts of academic integrity policies.

Secondly, while the pre-post design provides valuable comparative data, the absence of a control group in this quasi-experimental design means that observed improvements, while highly indicative, cannot be definitively attributed solely to MetaWiseGuide without ruling out all other potential confounding factors.

Thirdly, while the standardized grading rubric provided a structured basis for assessment and demonstrated clear alignment with observed improvements, future research could benefit from further validation of the rubric itself for its sensitivity to meta-literacy specific changes, and its explicit ability to detect and deter instances of plagiarism.

To build upon the promising groundwork of this study, future research should broaden its scope by involving larger, more diverse student samples and employing controlled experimental designs to strengthen causal claims regarding MetaWiseGuide's impact on academic performance and, specifically, on improving academic integrity and the accuracy of assessments. It is crucial to move beyond self-reported perceptions and assignment marks by incorporating more objective performance-based assessments, such as detailed rubric analysis, observation of search behaviors, and standardized meta-literacy tests, to capture nuanced improvements, including those related to plagiarism detection. Additionally, longitudinal studies are needed to investigate the long-term effects of MetaWiseGuide on students sustained academic honesty and responsible digital citizenship, alongside deeper qualitative methods like interviews to understand user experiences and pedagogical integration. Future work should also explore optimal curriculum integration strategies, instructor training, and targeted evaluations to measure specific improvements across all four meta-literacy domains, ensuring comprehensive app refinement that reinforces academic integrity in all aspects of student learning.

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