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Multiliteracies and Multimodalities in Flexible Learning Materials: A Quality Evaluation and Framework Development in Science Education

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ABSTRACT

In response to the COVID-19 pandemic, remote learning supplemented traditional face-to-face learning. Flexible learning materials (FLMs) mitigated its negative impact. In the new normal, FLMs continue to support in-person classes, especially during typhoons, high heat indices, and other environmental challenges. This study examined the integration of multiliteracies and multimodalities in FLMs used in science major courses at a Philippine teacher education institution. Employing a descriptive-correlational research design with 12 faculty respondents, the study used a validated survey instrument to assess the presence of visual, textual, and digital literacies, as well as visual, textual, and audio-visual modalities in FLMs. The quality of the materials was evaluated across content, instructional, and technical dimensions, and the relationships between faculty profile variables and quality assessments were analyzed using Spearman's rho.The findings revealed that multiliteracies (WM= 4.53–4.85) and multimodalities (WM= 4.55–4.62) were evident in FLMs, indicating a strong integration of visual, textual, and digital elements. The FLMs were rated "very satisfactory" across content (WM= 3.88), instructional (WM= 3.93), and technical (WM= 3.79) quality. However, improvements were needed for clearer visual annotations, deeper textual explanations of complex concepts, enhanced learner control, improved accessibility, and more precise synchronization of audio-visual elements. Correlation analysis showed a moderately positive association between faculty members' academic rank and teaching experience and their evaluation of content quality, but no significant association with instructional and technical quality. This suggests content evaluation is influenced by disciplinary expertise, while instructional and technical dimensions depend more on FLMs' inherent quality.The M³-CRAFT (Multiliteracies-Multimodal-Multilevel Co-Design Framework for Resilient, Adaptive, and Future-Ready Teacher Education) is proposed. It integrates faculty expertise, multiliteracy and multimodal principles, and quality assurance mechanisms to enhance FLMs. The proposed framework is designed to guide the development of inclusive, learner-centered, and resilient instructional materials. Empirical validation of its effectiveness in sustaining science education in flexible and disruption-prone learning environments is recommended for future research.

Keywords: *FLMs, multimodality, multiliteracy, science education, M³-CRAFT Framework*

INTRODUCTION

The COVID-19 pandemic has profoundly disrupted educational systems worldwide, compelling higher education institutions to rapidly shift from traditional face-to-face instruction to alternative delivery modalities. In this context, flexible learning environments have emerged as an important strategy to ensure continuity of

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

education (Cortes, 2020; Dayagbil et al., 2021). Central to this transition are flexible learning materials (FLMs), which support both synchronous (Anderton et al., 2021; Chen et al., 2005; Shumba & Munkuli, 2023) and asynchronous instruction (Abisado, 2020; Amiti, 2020, p.3).

Beyond their initial role as emergency interventions, FLMs have evolved into essential components of the "new normal" in education, particularly in contexts that experience frequent disruptions, such as extreme weather conditions, infrastructural limitations, and technological constraints (Müller et al., 20231). In the Philippine higher education system, FLMs play a significant role in sustaining teaching and learning processes, especially during typhoons, high heat index conditions, and other environmental challenges (Absolor et al., 2022; Tria, 2024, p.91).

Despite the increasing reliance on FLMs, concerns remain about their effectiveness in facilitating meaningful learning. Challenges such as reduced learner engagement, limited attention spans during synchronous sessions, and accessibility issues in asynchronous environments highlight the need for well-designed instructional materials (Bond, 2020, p.103842; GENÇ & Kesım, 2023, p.264; Mulenga & Shilongo, 2024, p.5). These challenges are particularly evident in science education, where complex and abstract concepts require structured and multi-representational approaches for effective understanding (Edelsbrunner et al., 2023, p.44).

To address these concerns, the integration of multiliteracies and multimodalities has gained prominence in instructional designs. The concept of multiliteracies, introduced by the New London Group (1996), emphasizes learners' ability to interpret and construct meanings across diverse modes of communication, including visual, textual, and digital forms. This reflects the evolving nature of literacy in a globalized and technologically mediated world.

In contrast, multimodality, grounded in Kress' (2009) work, focuses on the design and delivery of instructional content through multiple semiotic modes, such as text, images, audio, and video. While multiliteracies pertain to learner competencies, multimodality pertains to instructional representation and design. The interaction between these constructs is often explored for its potential to promote deeper understanding and engagement in learning environments (Sankey et al., 2010).

The integration of multiliteracies and multimodalities is particularly critical in science education. Scientific knowledge is often communicated through various means, including diagrams, graphs, simulations, and textual explanations (Tang et al., 2014, p.306). The coordinated use of these representations enhances conceptual understanding and supports inquiry-based learning (Edelsbrunner et al., 2023, p.45; McElhaney et al., 2014). However, the effectiveness of these approaches depends not only on their presence but also on how well they are integrated, aligned, and executed.

Although previous studies have highlighted the importance of multiliteracies (Navehebrahim, 2011; Zhang et al., 2018) and multimodalities (Johnson, 2013; Prain & Waldrip, 2006; Souza et al., 2026), limited empirical research has investigated their simultaneous integration in higher education science contexts. Existing studies have not adequately explored how multiliteracies and multimodalities influence the quality of flexible learning materials. Another underexplored area is the role of faculty profiles in evaluating instructional materials based on content, instructional design, and technical implementation.

To concretize this gap, the study examines the multiliteracies and multimodalities embedded in the FLMs used in science major courses, evaluates their quality across content, instructional, and technical dimensions, and determines their relationship with faculty profile variables.

This study contributes to the field by proposing an enhancement framework that synthesizes faculty expertise, multiliteracies and multimodalities, and multilevel quality assurance mechanisms for FLM development. Unlike stage-focused models such as ADDIE (Branch, 2009) or outcome-centered frameworks such as Backward Design (Wiggins & McTighe, 2005), which do not explicitly integrate quality assurance with context-responsive deployment, the researcher proposes an FLM framework that integrates all three dimensions to support the development of resilient, inclusive, and learner-centered instructional materials in flexible learning environments.

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

METHODS

Research Design

This study employed a descriptive-correlational research design to examine the multiliteracies and multimodalities embedded in flexible learning materials (FLMs) and determine their association with faculty profile variables.

The descriptive component was used to assess the extent to which multiliteracies, specifically visual, textual, and digital literacies, and multimodalities, namely visual, textual, and audiovisual modes, are present in the FLMs. It also served to evaluate the quality of these materials in terms of content, instructional, and technical dimensions. The correlational component was used to test the hypothesis that faculty profile variables, specifically, academic rank and teaching experience, would be positively associated with content quality evaluation, reflecting the influence of disciplinary expertise on content judgment. No specific directional hypothesis was proposed for instructional quality and technical quality; these dimensions were expected to be more standardized and less influenced by the evaluator's characteristics. This approach is appropriate for identifying statistical relationships among variables, without implying causation (Martínez-Sánchez et al., 2024, p.9296).

The instruments were utilized to collect quantitative data from faculty participants, enabling the systematic measurement of their FLM evaluations.

Research Locale and Participants

The study was conducted at a Philippine teacher education institution that implemented flexible learning modalities during the second semester of the School Year 2022-2023.

The respondents consisted of twelve (n = 12) faculty members from the Science Department who were teaching science major courses at the time of the study. Due to the limited population size, complete enumeration was employed to include all eligible participants.

The inclusion criteria were delineated as follows:

1. Must have taught at least one science major course for at least one semester; and
2. Must hold at least a master's degree in science or science education.

These criteria ensured that the participants possessed adequate disciplinary expertise and teaching experience to provide informed evaluations of the flexible learning materials.

Although complete enumeration ensured representation of the entire target population, the relatively small sample size (n = 12) limits the generalizability of the findings. Thus, the results should be interpreted as context-specific to the institution under study.

Data Analysis

The collected data were organized, tabulated, and analyzed using the appropriate statistical tools. Frequencies and percentages were used to describe the profiles of the faculty respondents. The weighted mean was used to assess the extent of multiliteracies, multimodalities, and quality of FLMs. Spearman's rank-order correlation coefficient (Spearman's rho) was used to determine the association between the faculty profile variables and FLM quality. This allowed the researcher to isolate the relationships between demographic variables and the quality of materials.

All analyses were performed using the Statistical Package for Social Sciences (SPSS), with statistical significance set at $p = 0.05$. This threshold dictates the cutoff for the inferences.

The strength of the correlation coefficients was interpreted as follows:

- 0.75 to 1.00 - High correlation
- 0.50 to 0.74 - Moderate correlation
- 0.25 to 0.49 - Low correlation
- to 0.24 - Negligible correlation

ISSN: 3116-3475
International Journal
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Volume 2 Issue 6 (June 2026)

It should be emphasized that the correlation analysis in this study identified statistical associations rather than causal relationships.

RESULTS AND DISCUSSION

Profile of Respondents

The study involved 12 faculty members teaching science major courses. The faculty members were divided into entry-level and advanced academic positions. A significant portion held Instructor (n = 4) and Assistant Professor (n = 4) ranks.

In terms of teaching experience, most respondents (n = 10) had over 11 years of service, while a substantial proportion (n = 4) had more than 20 years of teaching experience, suggesting a highly experienced evaluator group.

Regarding educational attainment, the respondents held both master's and doctoral degrees, reflecting strong academic qualifications well-suited for evaluating instructional materials.

This demographic distribution suggests an academically qualified and experienced faculty cohort capable of providing highly informed instructional material evaluations.

Multiliteracies in Flexible Learning Materials

The results indicate that multiliteracies are highly evident in the FLMs. Among the three domains, textual literacy received the highest ratings. It attained a weighted mean (WM = 4.85), demonstrating strong readability, coherence, and clarity of the written content. However, the indicator "the FLMs' texts clarify vague concepts …" addressing the explanation of complex concepts received a lower rating (WM = 4.70), suggesting limitations in fully clarifying complex topics.

Digital literacy manifested a high level of presence, with a WM = 4.63. This suggests that the materials effectively support digital resource access and technology integration in learning, despite inherent limitations in accessibility across diverse platforms and formats.

Visual literacy, although highly evident (WM = 4.53), received relatively lower scores for specific indicators like labeling, captioning, and clarity of visual explanations. This implies that while visual elements are present, their instructional support features need enhancement to enhance learners' interpretation.

Multimodalities in Flexible Learning Materials

The findings reveal that multimodalities are extensively employed in FLMs. The textual approach emerged as the most prevalent mode of instructional delivery, with a weighted mean (WM = 4.62), indicating that written content remains the primary means of presenting information. While it was crucial for explanation, it was less effective for engagement when used independently.

The visual approach was also evident (WM = 4.55), contributing to the representation and clarification of concepts. It was effective for understanding concepts but insufficient when used alone.

Similarly, the audiovisual approach demonstrated a high level of use (WM = 4.55), particularly in enhancing learning delivery and engagement. However, it was not consistently effective in promoting a deeper understanding.

Across all three approaches, the lowest-rated indicators consistently indicated that individual modes were insufficient when used independently. The findings suggest that no single mode of instruction was sufficient on its own. While visual and textual approaches support comprehension, and audiovisual approaches enhance engagement, effective learning occurs primarily through the purposeful integration of these modes. This highlights the role of multimodality as a coordinated instructional strategy in teacher training.

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

Quality of Flexible Learning Materials

The FLMs were evaluated as Very Satisfactory across all three quality dimensions: content, instructional, and technical.

Content Quality

Content quality received a high overall evaluation, with a weighted mean (WM = 3.88). The strongest indicator demonstrated a strong alignment with the CHED program standards and course objectives. The materials were also highly rated for their accuracy, organization, and incorporation of relevant scientific concepts.

However, the indicator related to inclusivity and the absence of bias (WM = 3.75) scored slightly lower than the dimension mean (WM = 3.88). While this rating still falls within the 'very satisfactory' category, it indicates that culturally inclusive representation requires further improvement.

Instructional Quality

Instructional quality yielded the highest overall rating among the three dimensions (WM = 3.93). Strengths included clearly-defined learning outcomes, appropriate cognitive levels, and higher-order thinking skills promotion. Instructional-quality metrics were prioritized.

However, relatively lower scores were observed in indicators related to learner control and integration of prior knowledge, indicating opportunities to strengthen learner-centered design features, particularly in supporting self-regulated learning.

Technical Quality

Technical quality, while still evaluated as very satisfactory (WM = 3.79), had the lowest overall mean among the three dimensions.

Strengths included clear and readable visual elements, effective user interface and navigation, and the availability of support materials. Lower ratings were observed for audio-visual synchronization, system stability, and accessibility features across devices.

These findings indicate that the technical aspects of FLMs require further refinement to ensure seamless and efficient learning experiences. While FLMs demonstrate high levels of content, instructional, and technical quality, their effectiveness can be enhanced through improved integration, accessibility, learner-centered features, and precise multimodal coordination.

Relationship Between Faculty Profile and FLM Quality

To assess the association between the faculty members' profile variables and FLM quality, Spearman's rho analysis at a 0.05 level of significance was used.

The results revealed that academic rank had a statistically significant moderate positive association with content quality ($p = 0.683$, $p = 0.014$). The length of experience also showed a statistically significant moderate positive association with content-quality ($p = 0.653$, $p = 0.021$). These findings indicate that faculty members with higher academic ranks or longer teaching experience tend to provide higher evaluations of the content-related aspects of the materials.

In contrast, the highest educational attainment did not show a statistically significant association with content quality ($p = 0.570$, $p = 0.053$). This suggests that formal education alone may not be as influential as teaching experience and professional exposure in evaluating instructional materials. However, the results were close to being significant. This implies a potential trend of higher educational attainment correlating with elevated evaluative scores, but evidence is insufficient to definitively establish a statistically significant association ($p = 0.053$).

Furthermore, none of the faculty profile variables (e.g., academic rank, length of experience, and educational attainment) showed a statistically significant association with instructional quality or technical quality ($p > 0.05$). This implies that the assessment of instructional and technical quality is consistently observable and standardized, thereby yielding uniform evaluation across diverse faculty profiles.

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

These findings imply that content evaluation is heavily influenced by professional experience and disciplinary expertise, while instructional and technical evaluations remain unaffected by the evaluator's profile.

Limitations

The author acknowledges several limitations in this study. First, the use of a small, institution-specific sample (n = 12) limits both generalizability and statistical power. Non-significant findings should be interpreted with caution, as the study may lack sufficient power to detect moderate relationships; the small sample size significantly limits the reliability of the results. Replication with larger sample sizes is essential. Second, the evaluation of FLMs was based solely on faculty perceptions, which may introduce subjectivity and reduce the critical assessment of weaknesses. The absence of student perspectives also limits the scope of the evaluation, particularly regarding learner experience and outcomes. Although faculty evaluations provide a rigorous assessment of pedagogical design, they remain an indirect measure that may not fully encapsulate the complex and multifaceted nature of the actual learner experience. Consequently, claims about learner engagement, comprehension, and satisfaction are based on faculty judgment rather than direct learner feedback, which may not fully reflect the actual student experience.

Future studies should include larger samples, multiple institutions, and student-centered evaluations to provide a more comprehensive assessment of FLMs. The use of triangulated data sources (e.g., student surveys, learning analytics, peer review) would also strengthen the validity.

Discussion

This study examined the integration of multiliteracies and multimodalities in flexible learning materials (FLMs) used in science education and evaluated their quality across content, instructional, and technical dimensions. These findings provide important insights into how contemporary instructional design principles are implemented within flexible learning environments that rely heavily on technology-mediated delivery and modularized content (Konstantinidou & Nisiforou, 2022, p.127; Özkan et al., 2025, p.138).

The results indicate that multiliteracies are strongly embedded in the FLMs, particularly in the domains of textual and digital literacy. This emphasizes the continued importance of structured textual explanations and technology-supported access to information. These results are consistent with the multiliteracies framework of The New London Group (1996), who emphasized the need for learners to engage with multiple forms of meaning in increasingly digital environments. Furthermore, the high evaluation of FLMs in facilitating digital information access aligns with Yuan et al.'s (2025) finding that digital literacy directly enhances learners' ability to effectively engage with e-learning environments and improves overall learning outcomes.

However, the comparatively lower ratings for visual literacy, particularly in terms of labeling, captioning, and explanatory support, highlight a limitation. In science education, visual representations, such as diagrams, models, and illustrations, play a central role in conveying abstract concepts. As noted by McTigue & Flowers (2011), comprehension of science texts involves not only decoding written language, but also interpreting diagrams. Insufficient annotation of visual elements may limit learners' abilities to interpret these representations effectively (Zheng et al., 2022).

This suggests that the presence of visuals alone is insufficient, and explicit instructional support is necessary to maximize their effectiveness. This observation is strongly supported by Galano et al. (2018, p.3), who found that while graphical representations are widely used, explicit guidance in interpreting them is often lacking. Similarly, research suggests that unsupported images can create a superficial illusion of understanding if not properly integrated with explanatory content (Jaeger & Fiorella, 2023, p.279).

With respect to multimodalities, the findings confirm that FLMs incorporate visual, textual, and audiovisual modes to a high degree. However, a consistent pattern emerged, indicating that no single modality is sufficient when used independently and that integrated usage is essential. This reinforces the theoretical foundation of multimodality, as articulated by Kress (2009), in which meaning is constructed through the interaction of multiple semiotic modes (Hung et al., 2012; Hurley, 2018, p.92; Putrawan & Nadira, 2026).

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

The dominance of textual approaches suggests that written content remains the primary mode of instruction. While textual materials provide detailed explanations, they may not fully sustain learner engagement when used alone, as confirmed by Kats et al. (2024), Sankey et al. (2010), and Tyrer (2021, p.4242). Conversely, while audiovisual materials contribute to engagement, they are less consistently effective in promoting deeper conceptual understanding without structured design (Mayer et al., 2001). As Valencia et al. (2023) emphasized, audiovisual materials enrich instruction but must support, rather than replace, structured content. These findings highlight the importance of coordinated multimodal integration to provide varied pathways for processing information (Moreno, 2006; Moreno & Mayer, 1999, p.366) while avoiding cognitive overload (Mayer et al., 2001; Sweller, 20231).

The evaluation of FLM quality further supports these observations. The content quality was rated highly, particularly in terms of alignment with curricular standards and conceptual accuracy. This indicates a strong disciplinary grounding for the study. As Capino & Errabo (2021) pointed out, adherence to prescribed learning competencies is crucial for the effectiveness of technology-integrated materials. Instructional quality also demonstrated strength, offering a positive contrast to earlier studies (e.g., Celeste & Osias, 2024, p.120) which highlighted challenges during technology implementation.

Nevertheless, several areas for improvement were identified. The relatively lower ratings in learner control and prior knowledge integration suggest that FLMs may not fully support self-regulated learning. Flexible learning inherently promotes learner autonomy (Chou & Zou, 2020, p.22; Laer & Elen, 2016, p.1413; Onah et al., 2022, p.85). However, research indicates that the absence of immediate teacher interaction necessitates higher student self-regulation skills (Boelens et al., 2017, p.5; Luo & Wang, 2023, p.1145774). The pandemic-induced shift to flexible learning in the Philippines further magnified this need, exposing challenges in terms of sustained attention and independent learning (Barrot et al., 2021, p.7323; Gocotano et al., 2021, p.267). Strengthening learner control features is essential to improve autonomy (Funa & Talaue, 2021, p.250; Mamun & Lawrie, 2023, p.25).

In terms of technical quality, although usability and navigation were rated positively, limitations were observed in audiovisual synchronization and system compatibility. These technical inconsistencies can disrupt learning by increasing cognitive load and reducing the coherence between instructional elements, such as the "split-attention effect" (Ayres & Sweller, 2005). This finding emphasizes that technical execution is integral to instructional effectiveness, particularly in multimodal environments.

Correlational analysis provides additional insights into the role of faculty characteristics in evaluating FLMs. The significant association between academic rank, teaching experience, and content quality suggests that disciplinary expertise enhances evaluative judgment of instructional content, which is consistent with Chang et al. (2014, p.8), Plander et al. (2025), and Ward et al. (2010, p.67). In contrast, the absence of significant relationships for instructional and technical quality indicates that these dimensions are less influenced by individual background and are more reflective of the inherent, standardized design of the materials.

This study demonstrates that while FLMs are generally of high quality, their effectiveness is not determined by the mere presence of multiliteracies or multimodal elements but by their purposeful integration, alignment, and coordination. This emphasizes the need for a systematic approach to instructional design that balances content accuracy, pedagogical effectiveness, and technical functionality. The results highlight the importance of collaborative development processes, faculty expertise, and technical optimization in enhancing the learning outcomes. These findings establish a strong empirical foundation for developing a structured framework that integrates these elements into a cohesive instructional design model suitable for the new normal. Collectively, research by Abuhassna et al. (2020, p.20) on online platform utilization, Oben & Xu (2025) on radical pedagogical innovation, and Webb et al. (2023, p.593) on institutional resilience offers a pedagogical grounding for establishing resilience as an academic foundation of the framework.

Based on these cumulative findings, this study proposes the development of the M³-CRAFT Framework (Multiliteracies-Multimodal-Multilevel Co-Design Framework for Resilient, Adaptive, and Future-Ready Teacher

ISSN: 3116-3475
International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

Education). This framework integrates multiliteracies, multimodalities, quality assurance mechanisms, and adaptive deployment strategies to enhance FLM development and utilization.

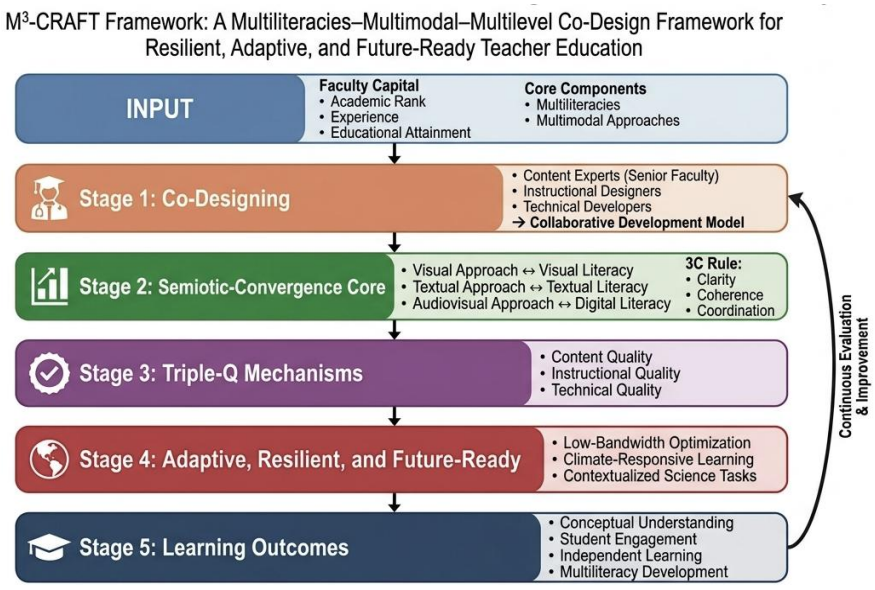
Proposed Framework for the Development of Flexible Learning Materials

The M³-CRAFT Framework, which stands for the Multiliteracies-Multimodal-Multilevel Co-Design Framework for Resilient, Adaptive, and Future-Ready Teacher Education, operationalizes empirical findings by mapping identified strengths and weaknesses directly into a structured process.

As illustrated in Figure 1, the M³-CRAFT Framework illustrates the integration of three core dimensions: Multiliteracies, Multimodality, and Multilevel Quality Assurance Mechanisms (M3) in flexible learning materials (FLMs). It integrates faculty expertise with M3 to ensure resilience in flexible learning environments. The framework emphasizes that effective FLMs are achieved through intentional integration, continuous evaluation, and responsiveness to real-world educational challenges.

The M³-CRAFT Framework operates through a structured, cyclical, five-stage process that transforms foundational inputs into measurable student outcomes; this study contends that this cycle maximizes pedagogical efficacy. This ensures that the resulting educational materials are responsive to contemporary pedagogical and environmental disruptions

Figure 1. *M³-CRAFT Framework*



Input: *Faculty Capital and Core Component*

The framework commences with foundational inputs, particularly the utilization of faculty capital. This encompasses the academic rank, teaching experience, and educational qualifications of the faculty members. These human resources are then combined with the core theoretical elements of the framework, which are the multiliteracies and multimodalities. This combination lays the groundwork for developing informed and pedagogically sound content.

Stage 1: Co-Designing

The initial phase of development adopts a Collaborative Development Model. Instead of working independently, the creation of learning materials draws on the collective expertise of content experts (senior

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International Journal
of Education, Research, and Innovation Perspectives
Volume 2 Issue 6 (June 2026)

faculty), instructional designers, and technical developers. This collaborative approach ensures that the materials are pedagogically sound, structurally sound, and technically feasible from inception.

Stage 2: Semiotic-Convergence Core

In this phase, the framework aligns instructional delivery with specific student literacies, grounding this process in transmodal reasoning. Recent perspectives, such as those by Prain et al. (2022), Tytler et al. (2022); and Unsworth et al. (2021, p.118) and frameworks extending representational meanings (Cheung & Erduran, 2025), highlight how meaning shifts across modes to facilitate deeper understanding in scientific contexts. This convergence is governed by the "3C Rule": Clarity, Coherence, and Coordination. This rule ensures that the integration of various modes, mapping visual approaches to visual literacy, textual approaches to textual literacy, and audio-visual approaches to digital literacy, does not overwhelm the learner, but rather creates a cohesive and synergistic learning experience.

Stage 3: Triple-Q Mechanisms

To ensure the effectiveness of the developed materials, they must undergo rigorous evaluation using Triple-Q (Quality) Mechanisms. This multilevel quality assurance gate assesses the materials across three distinct criteria: Content Quality (accuracy and alignment with curriculum), Instructional Quality (pedagogical effectiveness and engagement), and Technical Quality (usability, accessibility, and design). While the use of localized standards (i.e., CHED) is contextually appropriate, the Triple-Q mechanism also refers to established benchmarks for higher education online and hybrid science courseware (Baldwin et al., 2017, p.52; Vlachopoulos, 2016), such as the Quality Matters Rubric (Gold et al., 2025, p.5; Gregory et al., 2020, p.2

Stage 4: Adaptive, Resilient, and Future-Ready Deployment

The fourth phase prioritizes adaptability and resilience in response to the unpredictable nature of contemporary education. Resilience is framed not merely as technical continuity but as a pedagogical approach that integrates institutional and student-centered support. Drawing on Webb et al. (2023, p.593), this framework defines resilience as a multifaceted capacity for adaptation. Accordingly, learning materials are optimized for low-bandwidth environments to support equitable access, while climate-responsive strategies and contextualized tasks ensure content remains accessible during infrastructure challenges.

Stage 5: Learning Outcomes

The M³-CRAFT Framework aims to create positive and measurable impacts on learners. Materials developed using this framework are hypothesized to support enhanced conceptual understanding and engagement, as well as a greater capacity for independent learning. These expectations are supported by recent evidence regarding the efficacy of pedagogical agents in scaffolding self-regulated learning (Dever et al., 2024) and the positive impact of student-content interactions within inquiry-based online modules (Mamun & Lawrie, 2023, p.5). Although these findings provide a strong theoretical precedent for the holistic development of students' multiliteracies, empirical validation with student populations is required to confirm these outcomes.

The framework operates iteratively rather than linearly. A feedback loop establishes a connection between the final learning outcomes and the initial Stage 1 Co-Design process. This mechanism facilitates continuous evaluation and improvement, ensuring that the learning materials and educators who design them remain agile, adaptive, and consistently aligned with the evolving needs of future-ready teacher education.

CONCLUSION

This study examined the integration of multiliteracies and multimodalities in flexible learning materials (FLMs) used in science education and evaluated their quality across content, instructional, and technical dimensions. These findings lead to several important conclusions.

The findings indicate that FLMs are generally well developed and aligned with contemporary instructional practices, demonstrating a strong incorporation of visual, textual, and digital literacies, as well as multiple modes of instructional delivery.

Faculty evaluations suggest that the quality of FLMs may be enhanced through the purposeful integration and coordination of multiliteracies and multimodal elements, although the relationship between these design features and student learning outcomes requires empirical investigation. While textual content provides clarity and structure, visual and audio-visual elements contribute to conceptual understanding and engagement. Nonetheless, when these modes are used independently or are not properly aligned, their contribution to learning becomes limited.

The study highlights that content quality is associated with faculty expertise, as evidenced by the significant relationship between academic rank, teaching experience, and content evaluations. In contrast, instructional and technical quality appear to be more consistent across evaluators, implying that these dimensions are primarily influenced by the inherent quality of the materials (e.g., design and structure) rather than by individual evaluator attributes.

Despite the overall positive evaluation, several areas for improvement were identified, including enhancing visual annotation, deepening textual explanations for complex topics, strengthening learner-centered features such as self-regulation, prior-knowledge integration, and improving technical execution, particularly in audio-visual synchronization and cross-platform accessibility.

The findings indicate that effective FLMs combine content expertise, pedagogical design, and technical optimization. This study contributes to the field by providing empirical evidence on the role of multiliteracies and multimodalities in FLM quality and offering a basis for systematic improvement.

FLMs must be designed for more than pedagogical effectiveness. Given the Philippines' vulnerability to climate-related disruptions, FLMs must function as resilient instructional tools that support continuous learning in various environments. This requires not only quality design but also adaptability in contexts characterized by environmental and technological constraints.

Structured frameworks must be developed to guide the design and implementation of FLMs. The proposed M³-CRAFT Framework provides a systematic enhancement design. Its structured, data-driven process integrates faculty expertise, aligns multiliteracies with multimodal design, ensures quality through institutional mechanisms, and supports flexible and resilient learning environments.

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