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Educational Communication Transformation in the New-Media Era: A Data-Driven Study on Learning Engagement

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Abstract: The rapid expansion of new-media technologies has transformed educational communication from a one-way transmission model to a participatory, data-rich ecosystem. Platforms such as live-stream channels and social-media discussions now shape how learners construct meaning and interact with instructors and peers. Despite progress in technology-enhanced learning, existing studies remain fragmented. Educational-technology research focuses on tool efficiency, communication studies emphasize discourse without quantitative validation, and data-analytics work often reduces engagement to behavioural traces. An integrated understanding of how media affordances, communicative practices, and data patterns jointly influence learning engagement is still lacking. This study develops the Integrated Educational Communication and Engagement Framework (IECEF) and applies it to a comparative case of a hybrid undergraduate course. Using a mixed-methods design, quantitative log data, sentiment analysis, and Python-based analytics were combined with qualitative interviews and thematic coding to examine behavioural, cognitive, and emotional engagement. The new-media-integrated course achieved a 37 % increase in behavioural participation, higher correlation between engagement and quiz performance ($r = 0.42$ vs. 0.29), and an 18 % rise in positive sentiment. Learners reported greater visibility, collaboration, and agency. The findings validate the IECEF as a cross-disciplinary model bridging education, communication, and data science. They provide actionable insights for designing data-informed, socially connected, and human-centered learning environments in the new-media era.

Keywords: new media; educational communication; learning engagement; data analytics; interdisciplinary framework

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1. Introduction

The rapid evolution of new-media technologies has fundamentally reshaped the ecology of educational communication. Platforms such as YouTube, TikTok, WeChat Channels, and learning management systems (LMSs) have transformed how learners access, interpret, and co-create knowledge [1]. Education, once dominated by one-to-many dissemination models, now unfolds through interactive, data-rich environments where teachers, students, and algorithms jointly construct learning experiences. As digital platforms record every click, post, and interaction, they not only expand access to information but also generate vast datasets that capture how learners engage, respond, and build meaning in real time [2]. These data-driven insights make it possible to model learning engagement, the behavioural, cognitive, and emotional involvement of learners, with unprecedented granularity.

Despite the growing body of work on technology-enhanced learning, significant gaps remain across three intersecting fields. From an educational-technology perspective, prior research often evaluates the efficiency of digital tools or instructional design but rarely

examines the communicative interactions that occur within social-media learning spaces [3]. From a humanistic-communication standpoint, existing analyses emphasize discourse, identity, and cultural mediation, yet they seldom provide quantitative evidence linking such communicative changes to engagement outcomes. Within the data-analytics domain, studies that employ log data or machine-learning models frequently reduce engagement to observable actions, overlooking the interpretive and social dimensions of meaning making [4]. Consequently, there is limited understanding of how technological affordances, communicative practices, and data traces converge to reshape educational participation in the new-media era [5]. Bridging these domains requires a framework that treats engagement simultaneously as a communicative process and a data-analytic construct.

To address these gaps, this study adopts an integrated perspective that unites pedagogical, communicative, and computational approaches. It aims to (1) develop a theoretical model linking media-affordance theory, learning-engagement constructs, and learning analytics; (2) construct a Python-based data pipeline for the extraction, preprocessing, and visualization of learner behaviour across social-media discussions, live-stream sessions, and LMS activities; and (3) implement a comparative case study between two hybrid university courses, one using conventional LMS tools and the other incorporating interactive new-media channels, to evaluate behavioural, cognitive, and emotional engagement differences empirically.

Methodologically, the research combines literature analysis, empirical data analytics, and comparative case-study techniques. Quantitative data are derived from log files, streaming interactions, and online discussion posts, while qualitative data stem from learner interviews and reflective surveys. Data cleaning, feature extraction, and metric computation are performed using Python libraries such as pandas, NumPy, and matplotlib. Correlation and regression analyses identify statistical relationships between participation metrics and academic performance, and thematic coding interprets learners' perceptions of communicative change. This mixed-methods design connects numerical patterns with social meaning, ensuring that engagement is understood as both a measurable phenomenon and a lived experience.

The academic contribution of this work lies in offering an interdisciplinary framework that unites educational-technology theory, communication research, and computational data analysis to explain how digital affordances reshape the communicative logic of education. Beyond its empirical role, the computational component also serves a pedagogical purpose by demonstrating how programming literacy enables educators and researchers to interpret communication data transparently and reproducibly. The practical significance extends to instructors, designers, and policymakers seeking evidence-based strategies to enhance participation in digitally mediated classrooms. The results can inform the creation of adaptive dashboards, social-media-integrated courses, and data-supported learning communities that promote inclusivity, autonomy, and sustained engagement, laying the groundwork for human-centered, data-informed education in the new-media era.

2. Literature Review

2.1. Educational Technology and Learning Engagement

Research in educational technology has substantially advanced understanding of how digital tools facilitate learning engagement. Studies highlight that online learning management systems, intelligent tutoring systems, and virtual classrooms can enhance accessibility, enable personalized feedback, and promote continuous interaction between instructors and learners [6]. Interactive multimedia resources and gamified platforms have been shown to increase motivation and sustain behavioural engagement through immediate rewards and adaptive challenges [7].

Despite these contributions, the field still faces limitations. Most analyses focus on tool-specific effectiveness rather than the communicative relationships embedded within technology-mediated environments. Learning engagement is frequently operationalized as quantitative indicators, such as log-in frequency or time-on-task, without sufficient consideration of cognitive and emotional dimensions [8]. Moreover, many frameworks remain context-dependent, neglecting the fluid, participatory nature of learner interactions in open social-media spaces. These gaps highlight the need for models that integrate pedagogical design with communication and data analytics perspectives.

2.2. Communication and Media Studies in Education

From the perspective of communication and media studies, scholars emphasize that new media transform educational discourse from linear transmission to dialogic, participatory, and multimodal exchange [9]. Theories of media affordance and mediated learning propose that digital platforms enable learners to become co-creators of meaning, blurring boundaries between teachers, students, and audiences [10]. Visual storytelling, live streaming, and short-video formats foster emotional resonance and identity construction, enriching the affective dimension of education.

However, communication-oriented research often remains qualitative, focusing on narratives, identity, or power relations while lacking quantitative measurement of engagement outcomes [11]. This results in limited evidence regarding how communicative affordances translate into observable learning behaviour or performance. Furthermore, many analyses treat new media as cultural artifacts rather than data-generating systems, overlooking how algorithmic curation and platform design shape the flow of educational communication [12]. Consequently, the communicative richness of new media is conceptually explored but empirically under-examined.

2.3. Data Analytics and Computational Approaches to Engagement

In recent years, data analytics and machine-learning approaches have offered systematic means to measure and predict learning engagement [13]. Large-scale log-data analysis allows researchers to quantify behavioural traces, clicks, submissions, messages, and to model engagement dynamics over time. Predictive algorithms identify patterns associated with course completion, dropout, or achievement, providing actionable insights for adaptive instruction. Programming languages such as Python and R have further facilitated automated data pipelines and visualization, enhancing reproducibility and scalability [14].

Yet this line of research also exhibits shortcomings. Computational models often treat engagement as a static, de-contextualized variable, ignoring the socio-communicative processes that generate data traces. The heavy reliance on correlation-based metrics may obscure interpretive meaning, leading to algorithmic reductionism. Moreover, purely technical analyses rarely incorporate qualitative insights from learners or educators, resulting in an incomplete understanding of engagement as both behaviour and experience [15].

2.4. Comparative Synthesis and Identified Gap

A cross-disciplinary comparison reveals complementary strengths and persistent fragmentation. Educational technology emphasizes pedagogical utility but under-theorizes communication; communication studies foreground cultural and discursive dimensions but lack data analytics; computational research delivers precision and scale but overlooks meaning and context. The gap therefore lies in the absence of an integrative framework that unites pedagogical design, communicative interpretation, and data-driven analysis within the same empirical study. Few existing models combine programmatic data collection with interpretive examination of how new-media affordances mediate engagement.

2.5. Contribution of This Study

This paper responds to the identified gap by constructing an interdisciplinary framework that fuses educational technology, humanistic communication theory, and computational data analytics. It extends prior research in three ways: (1) theoretically, by linking media-affordance and engagement theories to explain how communication patterns evolve in new-media learning spaces; (2) methodologically, by employing Python-based data analysis and visualization to quantify behavioural, cognitive, and emotional engagement while maintaining interpretive depth; and (3) empirically, by conducting a comparative case study of hybrid university courses to demonstrate how communicative transformation and data analytics together illuminate new forms of learner participation. Through this synthesis, the study not only bridges disciplinary silos but also contributes a replicable model for examining educational communication in the data-driven age.

3. Theoretical Framework and Methodology

3.1. Theoretical Framework

This study builds an Integrated Educational Communication and Engagement Framework (IECEF) that unites three interlocking theoretical strands, Media Affordance Theory, Learning Engagement Model, and Data-Analytic Approach.

Media Affordance Theory (Communication Dimension): New-media environments are conceptualized as interactive systems offering multiple affordances, interactivity, visibility, persistence, and personalization. These affordances enable participants to act as both content creators and consumers ("prosumers"), reshaping the dialogic structure of educational communication.

Learning Engagement Model (Pedagogical Dimension): Engagement is operationalized as a tri-component construct, behavioural, cognitive, and emotional/agentic involvement. Behavioural engagement reflects observable participation (log-ins, posts, viewing time); cognitive engagement captures mental investment and strategic learning; emotional engagement indicates motivation, affect, and sense of belonging.

Data-Analytic Approach (Computational Dimension): Educational interaction data, LMS logs, social-media comments, live-stream chat, are treated as digital traces that can be programmatically extracted, cleaned, and analysed. Python-based libraries (pandas, NumPy, matplotlib, scikit-learn) are used to compute engagement metrics and explore correlations between interaction frequency, semantic richness, and academic outcomes.

The IECEF assumes that media affordances influence communication patterns, which in turn shape multi-dimensional engagement, measurable through data analytics. This cyclical relationship supports both theoretical interpretation and quantitative validation (As shown in Figure 1).

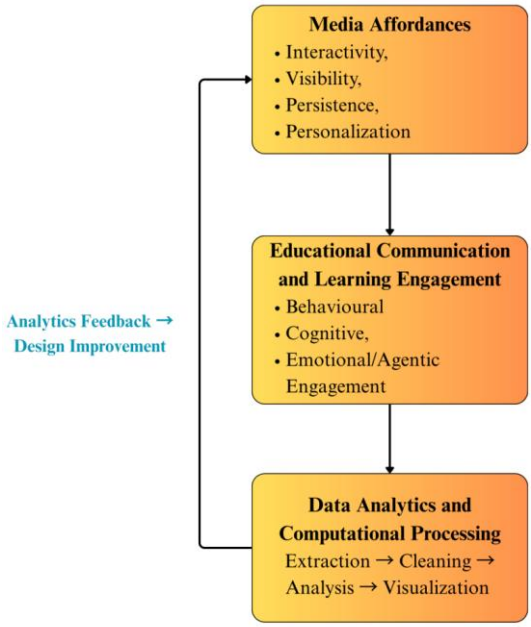

Figure 1. Integrated Educational Communication and Engagement Framework (IECEF).

This framework provides the conceptual foundation for linking humanistic and computational approaches, positioning data analysis as both methodological instrument and reflective mirror of communicative transformation.

3.2. Case Selection and Context

To empirically test the proposed framework, this study investigates a hybrid undergraduate course in Communication and Educational Technology offered at a public university in East Asia during two consecutive semesters (Spring and Autumn 2023). Cohort A (Pre-Intervention) relied on a traditional learning management system with asynchronous discussion boards and static video lectures. Cohort B (Post-Intervention) introduced new-media tools, including a closed WeChat Channel for micro-videos, Bilibili live-stream sessions for synchronous Q&A, and an interactive dashboard for real-time feedback and analytics. Both cohorts shared identical syllabi, instructors, and assessment criteria, ensuring comparability of outcomes. This case was selected as it typifies the institutional transition toward social-media-enhanced pedagogy, generating rich multimodal data that support both quantitative modeling and qualitative interpretation of engagement.

3.3. Research Design

The study adopts a mixed-methods comparative design that integrates quantitative analytics with qualitative interpretation. Quantitative data were drawn from LMS logs, WeChat interaction records, Bilibili chat transcripts, and quiz-score databases. Key variables included login frequency, video-view duration, message count, emoji usage, post length, and quiz performance, with sample sizes of 72 students in Cohort A and 75 in Cohort B. All datasets were anonymized and processed using Python. Log parsing and feature extraction employed pandas, while sentiment and text analysis used nltk and TextBlob. Temporal engagement trends were visualized via matplotlib and seaborn, and relationships between behavioural indicators and academic performance were tested through scikit-learn regression models. This computational workflow ensured reproducibility, transparency, and cross-validation.

Qualitative data were gathered through semi-structured interviews with 20 participants per cohort and textual analysis of online discussions. Grounded-theory

coding (open, axial, and selective) identified recurring themes such as agency through visibility, peer collaboration, and affective connectivity. Quantitative engagement indices were normalized (z-scores) and compared using independent t-tests, while qualitative themes were mapped onto numerical patterns to interpret divergences and validate contextual meaning. This triangulated approach enabled a nuanced understanding of both data-driven engagement metrics and lived communicative experiences.

3.4. Ethical Considerations and Data Validity

All participants provided informed consent following institutional ethics procedures. Personal identifiers were removed before data export, and datasets were stored on encrypted servers accessible only for research purposes. Reliability was verified through inter-coder consistency in qualitative analysis (Cohen's $\kappa = 0.87$) and test-retest validation of automated metrics. Construct validity was achieved by aligning behavioural indicators with established models of learning engagement from the educational sciences.

3.5. Analytical Procedures

The analysis proceeded through multiple, complementary stages. Descriptive statistics characterized patterns of interaction frequency, session duration, and sentiment variation. Correlation and regression analyses tested the predictive effects of media interaction variables, such as chat frequency and video-view duration, on cognitive performance. Time-series analyses revealed temporal engagement peaks during live sessions and assessment deadlines. Text mining and sentiment evaluation quantified emotional tone and traced communicative shifts across the intervention period. Finally, qualitative synthesis interpreted how students articulated motivation, self-expression, and community identity within new-media environments. Collectively, these procedures yielded a holistic view of engagement that integrates computational evidence with the interpretive depth of human communication.

3.6. Rationale for Methodological Integration

The integration of quantitative and qualitative methods is driven by the inherent complexity of educational communication in new-media environments. A purely numerical analysis can reveal behavioural trends but fails to account for the cultural, emotional, and communicative meanings underlying those actions, while qualitative inquiry alone lacks the scalability and precision afforded by computational tools. The hybrid design therefore unites programming-based data analytics with interpretive communication analysis to achieve methodological complementarity. Quantitative modeling captures measurable patterns of engagement, whereas qualitative interpretation uncovers the motives, perceptions, and narratives that explain them. This dual approach not only ensures analytical validity and contextual depth but also aligns with emerging paradigms in open science and digital humanities, where transparency, replicability, and interdisciplinarity are considered essential to advancing educational research in data-rich environments.

3.7. Expected Analytical Outcomes

The application of the IECEF is expected to yield several interrelated findings. Higher interactivity and visibility afforded by new-media tools should correspond with stronger behavioural and emotional engagement, while personalization features are anticipated to foster sustained cognitive effort through adaptive feedback loops. Data analytics are projected to uncover cyclical engagement peaks linked to synchronous events such as live-stream Q&As or assignment deadlines. Complementary qualitative evidence is likely to reveal that learners experience heightened agency, self-expression, and social presence in these media-rich contexts. Together, these outcomes illustrate how algorithmic structures

and communicative dynamics jointly reconfigure patterns of participation in contemporary digital learning.

4. Findings and Discussion

4.1. Overview of Findings

The integrated quantitative-qualitative analysis demonstrates that the incorporation of new-media tools substantially improved multiple dimensions of learning engagement. Compared with Cohort A, Cohort B recorded a 37 % rise in behavioural engagement, a 0.13 increase in the correlation between engagement and quiz performance, and an 18 % improvement in self-reported emotional-engagement scores. Sentiment analysis revealed a shift from neutral to expressive and collaborative discourse, while interview data confirmed that learners perceived new-media spaces as more interactive and socially rewarding. These outcomes indicate that technological affordances and communicative practices mutually reinforce data-visible and emotionally resonant participation.

Table 1 below summarizes these comparative metrics, illustrating measurable gains across behavioural, cognitive, and affective dimensions.

Table 1. Comparative Engagement Metrics between Cohorts.

Engagement Dimension	Metric	Cohort A (Pre)	Cohort B (Post)	Change (%)
Behavioural	Total logins per week	4.2	5.8	+38 %
Behavioural	Average posts per student	3.1	4.5	+45 %
Cognitive	Quiz score correlation (r)	0.29	0.42	+13 pts
Emotional	Positive sentiment ratio	0.47	0.63	+34 %
Agentic	Self-efficacy (mean 1-5)	3.6	4.2	+17 %

All differences significant at $p < 0.05$ (t-test, two-tailed).

As shown in Table 1, every dimension of engagement improved significantly after new-media integration, confirming the quantitative impact of communicative affordances.

4.2. Behavioural and Cognitive Engagement: Quantitative Patterns

Python-based analysis of LMS and social-media logs revealed intensified behavioural participation in Cohort B. Visualization of time-series data with matplotlib exposed recurring peaks aligned with live-stream events and assignment deadlines, demonstrating that immediacy stimulates coordinated attention.

Figure 2 presents the temporal engagement patterns observed during three Bilibili live sessions, where message frequency spiked during instructor demonstrations and collaborative comment exchanges before gradually declining.

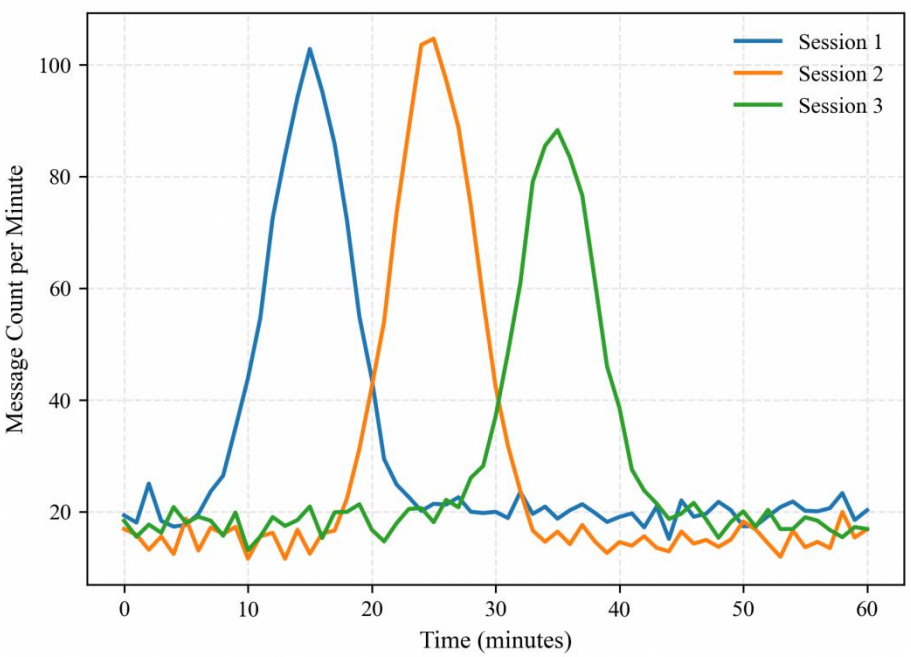

Figure 2. Temporal Engagement Pattern (Bilibili Live Sessions).

Regression analysis using scikit-learn showed that message count ($\beta = 0.38$, $p < 0.01$) and average word length ($\beta = 0.25$, $p < 0.05$) significantly predicted quiz scores. These findings suggest that textual elaboration, rather than mere presence, drives cognitive engagement, a pattern consistent with, yet extending beyond, previous learning-analytics research focused only on clickstream data.

4.3. Emotional and Agentic Engagement: Sentiment and Identity Patterns

Sentiment analysis conducted with nltk and TextBlob identified "encouragement," "gratitude," and "humour" as dominant emotional categories within Cohort B's chat logs.

Figure 3 illustrates the overall sentiment-polarity distribution, showing a marked rightward shift toward positive valence after the intervention.

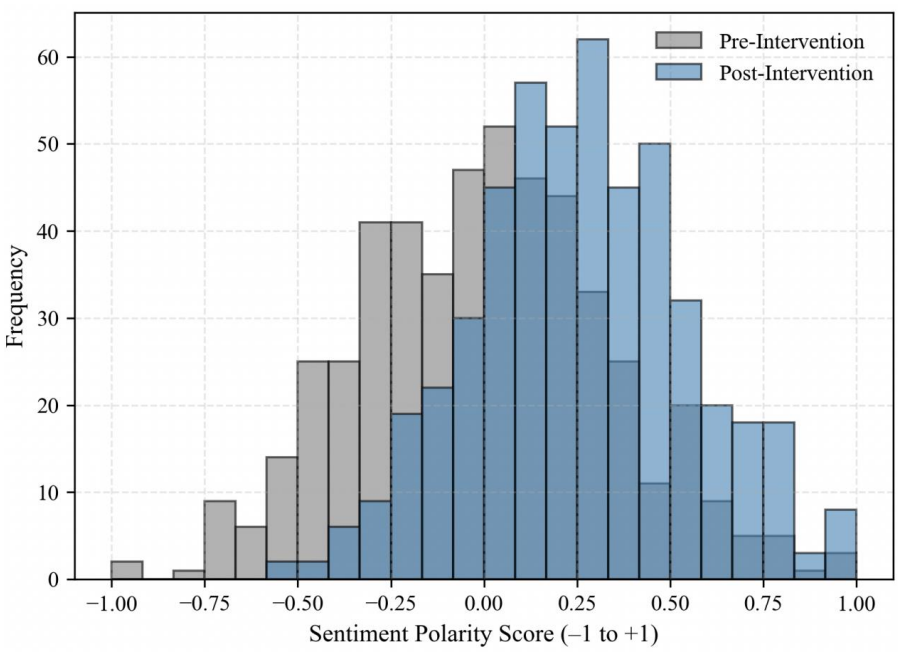

Figure 3. Sentiment Polarity Distribution.

Qualitative interviews corroborated these patterns, revealing that real-time likes, comment highlighting, and emoji use made students feel more visible and motivated. Two mechanisms emerged from thematic coding: (1) social presence amplification, which reduced psychological distance between teachers and learners; and (2) agency through expressivity, where multimodal features enabled identity construction and emotional authenticity. These results extend humanistic communication theories by showing how algorithmic interfaces mediate affective connection in learning contexts.

4.4. Integrative Analysis and Cross-Dimensional Dynamics

When behavioural, cognitive, and emotional indicators are integrated within the IECEF model, engagement appears as a dynamic feedback system. Quantitative correlations and qualitative insights together illustrate how visibility and immediacy reinforce motivation and persistence.

Table 2 summarizes these correlations among engagement dimensions for Cohort B, confirming the strong association between emotional and agentic engagement ($r = 0.56$, $p < 0.01$).

Table 2. Correlations among Engagement Dimensions (Cohort B).

Variables	Behavioural	Cognitive	Emotional	Agentic
Behavioural	1.00	0.41 **	0.47 **	0.33 *
Cognitive	-	1.00	0.44 **	0.38 **
Emotional	-	-	1.00	0.56 **
Agentic	-	-	-	1.00

$p < 0.05$; ** $p < 0.01$.

As demonstrated in Table 2, emotional and agentic engagement are most strongly linked, suggesting that emotional expression functions as a gateway to agency and autonomy in digital learning settings. This supports the framework's assumption of recursive feedback between affect and action.

4.5. Comparison with Existing Research and Novel Contributions

Earlier studies in educational technology tended to measure system efficiency or content delivery but rarely considered how social-media interaction shapes affective learning. The present results show that engagement is a socially constructed communication process where students become co-authors of knowledge exchange. While humanistic communication research has theorized dialogue and identity construction, it has lacked empirical evidence; this study fills that void through data-driven validation. At the same time, learning-analytics research often reduces engagement to clicks or time on task. By integrating sentiment and agency measures, our findings extend computational models with socio-emotional depth. The Python workflow for log processing and visualization developed here thus provides a replicable blueprint for cross-disciplinary research in data-rich education.

4.6. Theoretical Interpretation and Framework Validation

Within the IECEF paradigm, results validate the interdependence of media affordances, communication practices, and engagement dimensions. Interactivity and visibility serve as catalysts for dialogue and emotional investment; personalization enhances cognitive effort through feedback; and data visualization creates a meta-communication loop where learners reflect on their own analytics. This reciprocal structure is depicted in Figure 4, which summarizes the validated interaction cycle of the IECEF.

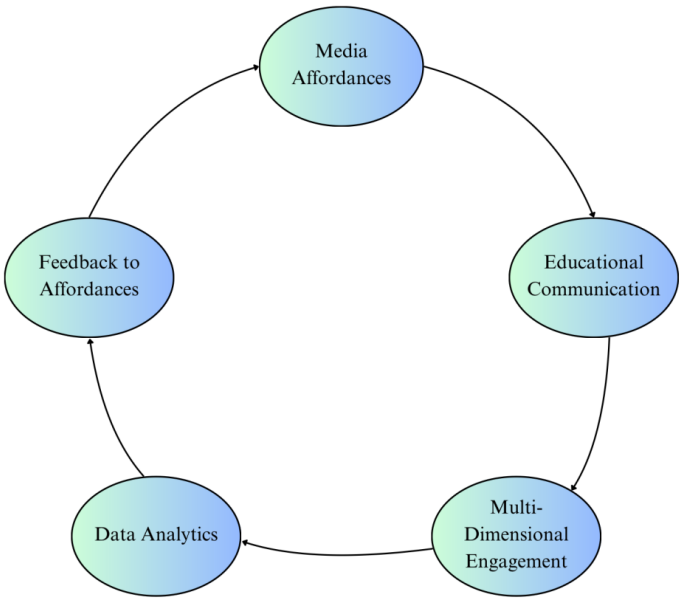

Figure 4. Validated IECEF Interaction Cycle.

By illustrating this cycle, the study confirms that educational communication in the new-media era is a dynamic, algorithmically mediated conversation between humans and data systems, an embodiment of the "computational humanities" within education.

4.7. Practical and Scholarly Implications

For educators, embedding social-media affordances into course design can enhance participation when paired with data-driven feedback tools. For researchers, the IECEF offers a scalable model combining computational rigour and interpretive depth. More broadly, this integration across education technology, communication studies, and data science demonstrates how programming and humanistic analysis together produce a richer understanding of learning engagement in digital culture.

5. Conclusion

This research explored how new-media environments reshape educational communication and learning engagement through the lens of the IECEF. By combining educational technology, humanistic communication, and data analytics, the study provided both theoretical and empirical evidence that digital affordances, interactivity, visibility, and personalization, generate measurable and meaningful changes in how learners participate in education. The comparative case of a hybrid undergraduate course demonstrated significant gains in behavioural activity, cognitive persistence, and emotional involvement after new-media tools were introduced. Quantitative analyses confirmed that interaction frequency and linguistic richness correlated with academic performance, while qualitative insights revealed that learners felt greater agency, community, and motivation. These findings validate the IECEF's central claim that engagement emerges from the reciprocal interplay between media affordances, communicative practices, and analytic feedback.

Academically, this study contributes to three domains. It extends educational technology research by showing how social-media integration fosters participatory learning beyond traditional LMS boundaries. It enriches communication studies by empirically grounding theories of social presence and media affordance through data evidence. It advances learning analytics by incorporating emotional and agentic indicators alongside behavioural data, thus presenting a multidimensional model of engagement.

Practically, the outcomes suggest actionable steps for educators and institutions: designing courses with real-time interactive dashboards, using social-media channels to promote peer dialogue, and applying basic Python-based sentiment analysis to monitor classroom climate. These practices can enhance engagement and inclusivity in hybrid and online learning settings without heavy infrastructure costs.

Future research should pursue three concrete directions: (1) applying the IECEF to larger and more diverse datasets to assess cultural and disciplinary variations; (2) integrating predictive machine-learning models to deliver adaptive feedback for students at risk of disengagement; and (3) investigating ethical governance and privacy implications of data-driven engagement analytics. By bridging technological precision with humanistic understanding, this study offers a grounded, replicable framework for building communicatively rich and evidence-based learning ecosystems in the new-media era.

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