Dark Matter of Learning: A Virtual Ethnography of Digital Underground Communities and the Socio-Emotional Infrastructure of Student Learning

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Keywords:	ABSTRACT
virtual ethnography; informal digital learning; socio-emotional support; WhatsApp learning communities	A Digital learning does not take place exclusively within formal platforms such as Learning Management Systems (LMS), but also emerges in informal and often invisible digital spaces beyond institutional control. This study examines how informal student WhatsApp communities function as a socio-emotional infrastructure that supports learning processes outside formal educational systems. Employing a qualitative virtual ethnography approach, data were collected through passive observation, digital documentation, and analysis of naturally occurring conversations and shared learning artefacts over one academic semester. Thematic analysis following Braun and Clarke's framework identified four interconnected themes: collaborative learning management, access and distribution of academic knowledge, emotional support and peer solidarity, and safe spaces for academic courage. The findings reveal that these informal digital communities operate as an alternative learning ecosystem that sustains students' academic engagement, emotional well-being, and willingness to participate intellectually. This study conceptualizes such communities as the "dark matter of learning" an invisible yet critical socio-emotional structure that underpins student learning beyond institutional LMS environments. The findings highlight the importance of recognizing and integrating informal digital learning spaces into a more holistic digital learning ecosystem.
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INTRODUCTION

The development of digital technology has fundamentally changed the way students interact, communicate, and build their learning practices. Learning activities are no longer limited to classrooms or formal platforms such as Learning Management Systems (LMS) but extend to various alternative digital spaces that are fluid, hidden, and run organically (Schilhab, 2017). Various studies show that digital technology contributes to the development of socio-emotional learning, technological literacy, and new forms of interaction that have implications for curriculum design and pedagogical practices (Bosman & Strydom, 2016; Hung et al., 2023). However, the transformation of this learning ecosystem also presents new challenges, such as participation gaps, academic

isolation, and social dynamics that differ from the context of face-to-face learning (Ilieva, 2011; Jeong et al., 2022).

In the context of online learning, students often rely on informal digital spaces including closed social media groups, anonymous forums, and instant conversation communities as alternative channels to exchange academic information, manage emotions, and build solidarity. However, the socio-emotional aspects of online learning are still poorly researched (Delahunty et al., 2014), including how informal spaces shape learning experiences, academic identities, and peer support mechanisms. Research on online learning is still dominated by studies that focus on formal platforms such as LMS, formal discussion forums, and institutional synchronous-asynchronous classes. The role of social media platforms for online community formation through media feeds can be customized for self-representation (Avenant, 2025)

Bibliometric analysis conducted on 2,275 Scopus articles published in 2016–2024 shows that digital education research focuses more on the technical aspects of online learning, motivational challenges, and satisfaction with LMS. These findings show a lack of attention to learning practices that take place in alternative digital spaces, whereas in these hidden spaces, students often develop creative learning strategies, share collective learning resources, and build emotional connections that are important for the sustainability of their studies. These invisible but crucial elements can be understood as "dark matter" of learning, which is a social-emotional structure that is not recorded in the formal education system but has a significant influence on the student learning experience.

Meanwhile, studies that use the virtual ethnography approach to understand student learning life in informal digital communities are still very limited. In fact, this method allows researchers to capture digital practices, interactions, and cultures that cannot be reached by survey approaches or conventional quantitative methods. Thus, there is an urgent need to explore how informal digital communities function as socio-emotional infrastructure that underpins the student learning process.

Based on the identified research gaps, this study aims to explore and analyze several key aspects of students' informal digital learning communities. First, this study aims to analyze how students build and manage learning coordination practices within digital underground communities. Second, this study seeks to examine the processes of access, exchange, and curation of academic knowledge that occur within students' informal digital communities. Third, this research aims to investigate how informal digital communities provide emotional support, solidarity, and affective stability for students in the context of online learning. Finally, this study aims to analyze how informal digital spaces create safe environments that enable students to demonstrate academic courage, acknowledge their lack of understanding, and take intellectual risks during the learning process.

Based on these research gaps, this study seeks to answer the following research questions:

1. How do students build and manage learning coordination practices in digital underground communities?
2. How does the process of access, exchange, and curation of academic knowledge take place in students' informal digital communities?
3. How do informal digital communities provide emotional support, solidarity, and affective stability for students in the context of online learning?
4. How do informal digital spaces create safe spaces for students to demonstrate academic courage, acknowledge ignorance, and take intellectual risks?

In line with the research question, this study aims to map and analyze ethnographically the role and meaning of informal digital learning communities formed by students as a socio-emotional infrastructure that supports their independent learning experiences. Using a virtual ethnography approach, this study contributes to the expansion of understanding of the social-emotional dimension in digital learning and offers a new perspective on learning practices that take place outside the formal spaces of educational institutions. This study contributes to digital learning research by conceptualizing informal WhatsApp communities as the socio-emotional "dark matter" that sustains student learning beyond institutional learning management systems.

This study is expected to provide both theoretical and practical benefits. Theoretically, it contributes to the expansion of digital learning literature by highlighting the significance of socio-emotional dimensions and informal learning environments that are often overlooked in mainstream educational research. Practically, the findings offer insights for educators, universities, and policymakers in designing more holistic digital learning ecosystems that recognize and support the role of informal student communities as complementary learning infrastructures.

Furthermore, the implications of this study emphasize the importance of integrating formal and informal digital learning spaces in higher education. Educational institutions are encouraged to reconsider the boundaries between official learning platforms and student-driven communities, recognizing that meaningful learning processes often emerge in informal environments where students experience emotional safety, peer solidarity, and collaborative knowledge construction. By acknowledging these hidden learning infrastructures, universities can develop more inclusive and adaptive digital learning strategies that better support students' academic and emotional well-being in the evolving landscape of digital education.

METHOD

Research Design

This study uses a qualitative approach with the virtual ethnography method, which was developed to understand the practices, culture, and dynamics of interactions that take place in online communities. Virtual ethnography was chosen because it allows researchers to observe digital footprints, communication patterns, and social activities that occur naturally in online communities without disrupting the flow of participants' interactions.

This approach is oriented towards a *thick understanding* of the social context, language, and relationships between members of the informal digital community that function as an alternative learning space for students.

Research Context and Setting

The study focused on learning-related interactions, excluding purely personal conversations unrelated to academic activities. The research was conducted on a student WhatsApp group that was used as an informal discussion space outside the campus formal learning ecosystem in Indonesia. This group was chosen purposively because of its intense interaction activities, the diversity of its members' academic backgrounds, and its role as *a digital underground learning community* that is not documented in the official LMS platform. Participants are students who are members of the WhatsApp group. The number of participants followed the number of active group memberships in the study period. The research time was located for 6 months or 1 semester. All participants' identities are anonymized to protect privacy. The research did not intervene or influence the conversation; The data used is a natural conversation that occurs in the flow of daily communication.

Data Collection Techniques

The data in this study was collected through three main techniques. First, digital documentation, which includes various forms of communication artifacts such as screenshots of WhatsApp conversations, memes, GIFs, stickers, lecture notes, collaborative documents, as well as external links such as Google Drive and YouTube. All of these documents were compiled to capture the context of student interaction naturally. Second, passive participatory observation, in which researchers observe conversation dynamics and interaction patterns without making any interventions. This technique is commonly used in virtual ethnography to maintain the authenticity of participants' digital behavior. Third, the collection of digital artifacts, which is all forms of communication expressions including text, emojis, humor, and information exchange patterns is carried out as a unit of ethnographic data that reflects social practices in the digital community. Data collection took place following a period of active interaction within WhatsApp groups that corresponded to the focus and purpose of the study.

Data Analysis Procedure

Data were analyzed using thematic analysis based on the Braun & Clarke framework. The analysis process is carried out through six stages (Braun & Clarke, 2006):

1. Familiarization with Data, at this stage re-reading entire conversations and digital artifacts to understand the context.
2. Initial Code Development, at this stage marks pieces of data relevant to the research focus.
3. Theme Search, at this stage groups the code into larger thematic patterns.
4. Theme Review, at this stage refines, compares, and assesses the consistency of the theme.
5. Defining and Naming, at this stage constitutes a final theme that represents the deep meaning of community practice.

6. The preparation of the Thematic Report, at this stage presents the theme in the form of an analytical narrative supported by data citations (which have been anonymized).

Data analysis is assisted using Atlas.ti software, which facilitates the process of coding, theme mapping, and tracing relationships between categories.

Ethical Considerations

This research follows the ethical principles of qualitative research and digital ethnography. The study was conducted through passive virtual ethnography in a student WhatsApp group as an informal digital learning space, without the intervention of researchers to maintain the naturalness of interaction. Participants were informed about the research objectives and the use of digital conversation data for academic purposes, as well as participating voluntarily.

All data is analyzed anonymously by removing personal identities, including names and phone numbers. Conversation excerpts are customized as necessary to prevent identity traceability. The data is stored securely and used solely for research purposes, in accordance with the principles of confidentiality and non-maleficence in digital ethnography.

RESULTS AND DISCUSSION
Research Results

The data collected in the thematic analysis identified four main themes that represent the function and meaning of the "dark matter of learning" or students' informal learning communities outside the LMS.

Table 1. Thematic Findings of Informal Digital Learning Communities

Theme	Core Description	Manifested Date
Collaborative Learning Management	Learning coordination is formed organically and horizontally through informal assignments, task reminders, and joint problem-solving.	Deadline reminder; division of roles; technical discussions; completion of collective tasks.
Access & Distribution of Academic Knowledge	The community serves as a repository of knowledge that students curated spontaneously and responsively.	Lecture notes; video tutorials; Google Drive files; Examples of previous tasks.
Emotional Support & Solidarity	Digital spaces become a place to share emotions, humor, validation of experiences, and psychological stability.	Memes; GIF; joint complaints; encourage each other.
Safe Space for Academic Courage	The community creates a safe zone to ask, give opinions, criticize, and demonstrate academic vulnerability.	Basic questions; criticism of lecturers' methods; answer test; critical discussion.

Source: Data Processed

Thematic analysis of WhatsApp conversations, digital documents, and other communication artifacts reveals four main themes that shape the socio-emotional infrastructure of students' informal digital learning communities.

Topic 1. Collaborative Learning Management

Students organically develop a stable and efficient learning coordination mechanism in WhatsApp groups. These practices include informal role sharing (e.g. note provider or material clarifier), deadline reminders, technical discussions related to tasks, and collective problem-solving. Interactions take place through a rapid rhythm of conversation, brief language, and the use of internal, mutually understood code. The coordinating structure is horizontal in the absence of a formal leader figure. This mechanism makes the process of organizing group assignments and solving academic problems more responsive than formal platforms such as LMS.

Topic 2. Access and Distribution of Academic Knowledge

This digital community serves as a repository of knowledge curated by the students themselves. Lecture notes, assignment samples, Google Drive links, YouTube videos, and technical guides are actively and repeatedly shared. The practice of sharing learning resources occurs spontaneously when there are members who need certain materials or experience difficulties. This pattern creates a fast, relevant, and need-oriented flow of information.

Topic 3. Emotional Support and Solidarity

This digital space provides a forum for students to express academic stress, stress, fatigue, and confusion. Responses in the form of humor, memes, GIFs, and stickers are used to ease tension. Students calm each other down, validate experiences, and provide motivation when facing tough tasks or declining emotional states. This emotional support consistently appears side by side with academic discussions.

Topic 4. Safe Space for Academic Courage

WhatsApp communities create safe conditions for students to ask questions, admit ignorance, try to answer difficult questions, and criticize lecturers' teaching methods without fear of being judged. Interactions are egalitarian, allowing students to experiment with arguments, check answers before class, and test understanding collectively. Academic courage grows through mutual trust and the absence of hierarchy.
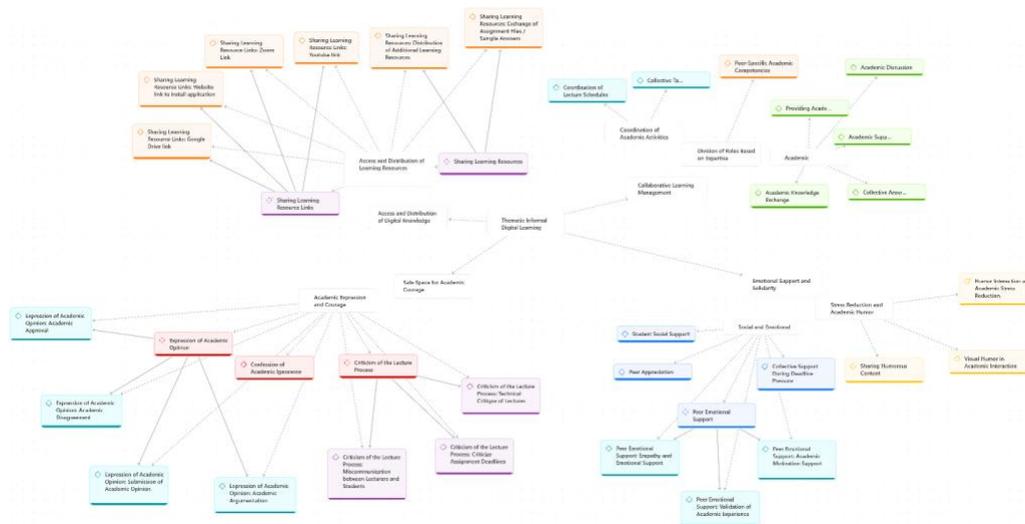
Figure 1. Thematic Informal Digital Learning Community using Atlas ti

Discussion

This section discusses how these four themes contribute to the understanding of the socio-emotional infrastructure that underpins student learning in informal digital spaces.

Topic 1. Collaborative Learning Management

The findings suggest that organically formed learning coordination can run efficiently without a formal structure. This is in line with the findings of Li et al., regarding role dynamics in online groups and support the idea that informal spaces can give rise to *productive cognitive conflicts* that enrich the learning process (Li et al., 2024). In addition, the existence of peer support has been shown to improve academic performance (Batz et al., 2015) and help students who have strong self-regulation to develop further (Chang-Tik & Goh, 2023), as well as informal meetings will build participation and collaboration (Chang-Tik et al., 2024). This kind of informal space can even work more responsive than LMSs that tend to be rigid.

Learning outcomes will be significantly better if they are guided directly than if students find themselves without adequate guidance (Alfieri et al., 2011). Cognitive presence in the community is related to learning outcomes (Akyol & Garrison, 2011). Informal spaces with active learning can greatly support students who already have good cognitive abilities and self-regulation. Informal spaces offer great potential, especially if designed or implemented with attention to how students with different levels of achievement receive appropriate support (Chang-Tik & Song, 2023). These findings confirm that digital spaces serve as a more responsive learning management platform than LMS, while facilitating equal participation without hierarchy.

Topic 2. Access and Distribution of Academic Knowledge

The finding that students form *a peer-curated knowledge ecosystem* expands (Hung et al., 2023) argument that effective digital learning relies on quick access to resources. Informal spaces not only accelerate access, but also facilitate the selection and distribution of knowledge based on solidarity. This is consistent with(Deng & Tavares, 2015) who

emphasize the importance of informal platforms as collaborative spaces that go beyond the formal boundaries of institutions.

Topic 3. Emotional Support and Solidarity

The affective function of informal digital communities supports the findings of (Lawrence, 2022) and (Lehtinen et al., 2023) that humor, emojis, and emotional expression increase *social presence* in online learning. In the context of increasing academic isolation in online learning (Jeong et al., 2022), this horizontal support strengthens students' psychological resilience and encourages academic engagement. This space also facilitates a balance between academic demands and emotional health (Song, 2025). Group collaboration leads to a positive view of the benefits of group work (team) and psychological understanding, as well as a more optimistic view to increase confidence in the learning process to improve learning skills (Alpay & Ireson, 2006)

Topic 4. Safe Space for Academic Courage

The academic courage that emerges from this safe zone reinforces the findings of (Adamson, 2024; Mäkelä et al., 2022)) about how strong the influence of emotional factors is on academic participation. Students tend to be silent not just because they don't understand, but because they are afraid of being judged or humiliated (Early & Norton, 2014; Mokgwathi & Webb, 2013; Sibomana, 2022; William & Ndabakurane, 2017). In the WhatsApp community, the performative pressure disappeared, resulting in the emergence of a larger academic agency. This expands on (Hobbs, 2013) view that digital improvisation is not only a cognitive process but also an emotional process and academic identity.

Integration Between Themes

The four themes found in this study do not stand as separate categories, but form a mutually reinforcing cycle in supporting the sustainability of student learning in the informal digital space. Organically built collaborative learning management mechanisms create a stable academic workflow that accelerates the process of access and distribution of knowledge within the community. When knowledge moves quickly and collectively, it strengthens emotional solidarity, as students feel supported both academically and affectively. This solidarity in turn creates a sense of security that allows the emergence of academic courage, namely students' readiness to ask questions, admit ignorance, and take intellectual risks without fear of being judged. Academic courage that grows in a safe atmosphere again improves the quality of coordination and collaboration in groups, thereby strengthening the continuous collective learning cycle. Thus, the four themes form an interdependent ecosystem of invisible networks that work "behind the scenes" and sustain the effectiveness of student learning processes. This subtle but highly influential structure constitutes the so-called *"dark matter of learning"*, which is a socio-emotional infrastructure that is not recorded in the formal education system but plays a significant role in the sustainability and depth of students' learning experience in the informal digital space.

Research Implications

This study has important theoretical and practical implications. Theoretically, it extends the discourse of digital learning by showing that student learning is not solely sustained by formal instructional systems such as Learning Management Systems, but also by informal and often invisible socio-emotional infrastructures created by students themselves. By conceptualizing informal WhatsApp communities as the "dark matter of learning," this study contributes a new analytical perspective to the field of digital education, particularly in understanding how emotional support, solidarity, trust, and academic courage shape meaningful learning experiences beyond institutional platforms.

Practically, the findings suggest that educators, universities, and policymakers need to reconsider the boundaries between formal and informal digital learning spaces. Higher education institutions should not view informal student communities merely as peripheral or unofficial spaces, but as complementary ecosystems that can strengthen academic engagement and student well-being. The study implies the need for more inclusive digital learning strategies that acknowledge peer-based support systems, foster emotionally safe environments, and integrate socio-emotional dimensions into the design of digital education policies and practices.

Research Limitations

This study has several limitations that should be acknowledged. First, the research focused on a single student WhatsApp community, which means that the findings are context-specific and cannot be generalized to all forms of informal digital learning communities. Different platforms such as Telegram, Discord, or other social media environments may produce different interaction patterns, communication cultures, and socio-emotional dynamics.

Second, the use of virtual ethnography relies heavily on the researcher's interpretation of naturally occurring digital interactions and artifacts. Although this method provides rich contextual insight, the possibility of interpretive bias remains. Third, the study only captures interactions that were visible within the observed group, while private messages, deleted content, or communication occurring across other platforms were beyond the scope of observation. Therefore, the findings should be understood as a partial but meaningful representation of students' informal digital learning practices.

CONCLUSION

This study shows that informal digital communities formed through WhatsApp groups function as an invisible yet crucial socio-emotional infrastructure in supporting students' learning experiences. Using a virtual ethnography approach, the research reveals that learning in digital spaces is not limited to the exchange of academic information but also involves social and emotional practices that shape the overall dynamics of learning. The four main themes identified—Collaborative Learning Management, Access and Distribution of Academic Knowledge, Emotional Support and

Solidarity, and Academic Courage Safe Space—demonstrate how students construct an alternative learning ecosystem that operates in parallel with the formal campus system. Organic coordination, rapid and collective knowledge distribution, stable emotional support, and the emergence of academic courage through a sense of psychological safety indicate that informal digital spaces perform pedagogical functions that formal platforms such as Learning Management Systems (LMS) cannot always fulfill. These findings confirm that digital learning should not be understood solely as a cognitive process but also as a social practice shaped by interaction, emotion, trust, and solidarity. However, this study has several limitations, including its focus on a single informal digital community in the form of a student WhatsApp group, which limits the generalizability of the findings to other platforms or communities, as well as potential interpretive bias and incomplete documentation of digital interactions. Therefore, future research is recommended to explore informal digital communities across other platforms such as Telegram, Discord, or anonymous forums and to integrate digital ethnography with in-depth interviews, participatory observation, and longitudinal studies to deepen understanding of the development of emotional support, learning coordination, and academic courage in digital learning environments.

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