

**A Case Study of Student Interaction Patterns in Health Science Education: Social
Network Analysis of Canvas and WhatsApp**

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Master's Thesis

Tartu 2025

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Abstract

This study explores the integration of Social Network Analysis (SNA) within Learning Analytics (LA) to evaluate student participation in asynchronous online learning environments. Using a mixed-methods case study approach, the interactions of 15 health science students were analyzed across two platforms: Canvas, representing a formal Learning Management System (LMS), and WhatsApp, serving as an informal communication channel. Qualitative thematic analysis was conducted on student-generated content, while quantitative metrics—degree centrality, betweenness centrality, and network density—were used to assess interaction patterns.

Findings revealed that WhatsApp demonstrated higher network density (≈ 0.28) and decentralized interactions conducive to peer support and spontaneous communication. In contrast, Canvas had lower density (≈ 0.19) and more centralized, instructor-driven interactions with selective engagement. High-performing students often exhibited high centrality across both platforms. These insights highlight the complementary roles of formal and informal platforms in supporting student learning.

This research suggests that educators can strategically integrate both types of platforms to foster academic engagement and community building. Furthermore, the study emphasizes the value of SNA as a diagnostic tool for formative assessment and targeted interventions. Limitations include the small sample size and the case study's contextual specificity. Future research should examine larger datasets and compare additional LMS and communication platforms.

Keywords: Social Network Analysis, Learning Analytics, Canvas, WhatsApp, Online Forums, Student Engagement, Asynchronous Learning

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I. Introduction

We as individuals or human kind are primarily social entities. Social networks are formed through various types of relationships among their participants, including political, institutional, familial, formal and informal, geographical, and other connections. Our motivation arises from an intrinsic need for social belonging, which we satisfy through the cultivation of interpersonal relationships (Isba et al., 2017). This intrinsic need for social belonging highlights the importance of understanding the patterns and structures of our social interactions, which has led to the increasing prominence of social network analysis (SNA) in the fields of social and behavioral sciences (Dawson, 2008b). Social network analysis is employed to examine institutions, individuals, groups, or any interconnected structures within a social framework, generating insights by drawing conclusions about specific individuals or groups (Sozen et al., 2009).

This analytical approach is particularly relevant in the context of education, where the integration of technology has expanded online learning platforms, including asynchronous forums that facilitate student interaction outside traditional classroom settings. Online Discussion Forums (ODFs) play a crucial role in student engagement, with Learning Management Systems (LMS) such as Canvas providing structured learning environments, while social media applications like WhatsApp foster informal communication (Najafi & Tridane, 2016a).

Educators increasingly rely on Social Network Analysis (SNA) to visualize and quantify interaction patterns in ODFs. SNA metrics, including degree centrality, betweenness centrality, and network density, provide insights into student engagement and collaboration (Gašević et al., 2018). These metrics, when combined with Learning Analytics (LA), enable targeted interventions that enhance learning outcomes (Dawson, 2008b). In the context of Learning Analytics (LA), these insights offer practical data that educators can leverage to improve educational outcomes by customizing interventions and promoting collaborative efforts. Prior research has shown that Online Discussion Forums (ODFs) are effective in facilitating collaborative learning and fostering a sense of community, particularly in asynchronous settings where students can take the time to reflect and contribute thoughtfully (Erlin et al., 2009; Suraj & Roshni, 2015; Yang et al., 2003).

During the COVID-19 lockdown and the subsequent transition back to face-to-face instruction, students utilizing asynchronous platforms like Canvas and WhatsApp achieved unexpectedly high success rates. This observation has piqued the interest of educators, who are keen to investigate the factors contributing to this outcome. A particular area of focus is the role of interaction patterns in supporting student achievement. By examining these patterns through the lenses of Social Network Analysis (SNA) and Learning Analytics (LA), educators can gain a deeper understanding of how asynchronous forums influence student learning outcomes. This analysis is expected to provide valuable insights into the mechanisms by which these platforms facilitate learning, thereby enabling educators to optimize their use in future educational settings. This study aims to examine the use of Social Network Analysis (SNA) as a Learning Analytics (LA) tool to evaluate student interaction patterns within a health science course, utilizing Canvas forums and WhatsApp groups. The case study seeks to understand how these different platforms influence learning outcomes, especially considering the observed increase in student success rates following the COVID-19 lockdown.

II. Literature Review

A social network consists of a collection of individuals and the connections or relationships established among them (Wasserman & Faust, 1994). The analysis of social networks stands apart from the individual-based methods that are prevalent in educational research and other studies within the social and behavioral sciences. What sets it apart is that, besides concentrating on the individual, it places significant emphasis on the relationships that link one individual to another. Social network analysis is more than just an analytical technique; it encompasses a collection of theories, models, and applications that are articulated through relational concepts and processes. Connections among individual units, such as students, teachers, or school districts, are a core element of social network analysis. As interest in social network analysis has increased in both the natural and social sciences, a consensus on key principles has developed, setting this approach apart from others. Wasserman and Faust (1994) highlight that social network analysis not only utilizes relational concepts but also emphasizes:

- a) Individuals and their actions are seen as interconnected.
- b) Relational ties between individuals serve as channels for resource exchange.
- c) The social structure, defined by the pattern of relations among individuals, can either facilitate or limit individual actions.
- d) Social network models view structure as persistent patterns of relationships among actors.

Social network analysis may thus be considered as an interdisciplinary research approach that conceptualizes social relationships in the form of nodes and ties, with nodes representing the individual players in a particular network and ties identifying the links between them (Akbar & Saritha, 2020). Social network analysis combines anthropology, sociology, mathematics, and computer science. It provides a systematic approach to visualizing and analyzing the interactions between network components. These entities, known as 'nodes', can be individuals, groups, organizations, or even computers, with relationships between them represented as 'edges' or 'links' or 'ties'. SNA not only maps these relationships, but also quantifies their properties, providing insights into the nature and strength of the connections.

SNA mathematical analysis measures network parameters at the individual and group levels. The mathematical analysis of SNA uses graph theory to construct metrics for nodes, linkages, and networks. Examples of network metrics include distance, number of interactions, and number of community bridges. These metrics help measure interactions, rank nodes, and

establish linkages (Saqr & Alamro, 2019). The approach enables the examination of network dynamics such as information flow, invention dissemination, and influence propagation. Various metrics, like as centrality, density, and betweenness, provide quantitative measurements for determining the importance of certain nodes, their level of interaction, and the degree of segregation or integration within the network (Putnik et al., 2016). These metrics facilitate to find out the influential nodes and assess the structure and the cohesion of the network between nodes.

Social network analysis (SNA) is a strong tool. It enables us to investigate the underlying structure of an organisation or network, finding the formal and informal linkages that underpin formal procedures and results. SNA may provide insight into human interactions inside an organization and identify broader patterns of social interaction across contexts (Agneessens & Labianca, 2022). This knowledge may lead to improved communication, easier change management, and more efficient teamwork.

This technique also aids in demonstrating the impact of relationship-building and system reform activities by comparing changes in the quality and number of relationships before and after the project. SNA's maps and visualizations provide a compelling method to share your progress and effect with stakeholders, sponsors, and the community at large. Social network analysis investigates the social connections among members of an organization, which can be linked to demographics, attitudes, behaviors, and cognitive processes. These social connections may impact individual and group outcomes, such as well-being, creativity, and performance. However, gathering social network data within an organization can be challenging due to a lack of expertise in network analysis and concerns regarding data protection (Agneessens & Labianca, 2022).

From the perspective of management science, social network analysis is a valuable tool for examining strategically significant networks within an organization. This analytical method allows for the identification of informal groups that may not be immediately visible through traditional organizational charts (Aydin, 2018). By recognizing these informal groups, management can engage with key individuals and groups to foster effective collaboration. This, in turn, can enhance communication, streamline processes, and ultimately contribute to the organization's overall efficiency and success.

II.1. Social Network Analysis (SNA) in Education

Social Network Analysis (SNA) serves as a modeling technique and analytical approach suitable for identifying and analyzing the structural characteristics of supply networks, as well as the relational patterns among the entities or groups participating in these networks (Fouad & Rego, 2024). SNA provides quantitative measures of student interactions, allowing educators to identify key participants and assess engagement levels. Previous studies have demonstrated that SNA is a powerful tool for mapping student interactions, especially in asynchronous environments where direct observation is not feasible (De Laat, Lally, Lipponen, & Simons, 2007). Social Network Analysis (SNA) offers quantitative metrics to assess students' positions within a network. These metrics include degree centrality, which reflects a student's direct interactions; betweenness centrality, which gauges a student's role as a bridge between different groups; and network density, which measures the overall connectivity within the network (da Silva et al., 2019; De Laat, Lally, Lipponen, Simons, et al., 2007a; Gašević et al., 2018; Yang et al., 2003). These metrics enable educators to pinpoint influential students and evaluate the structure and cohesion of the student network. Social Network Analysis (SNA) is particularly valuable for mapping student interactions within Online Discussion Forums (ODFs), especially in asynchronous settings where direct observation of student engagement is difficult (da Silva et al., 2019).

II.2. Social Network Analysis of Education Forums

Research in Social Network Analysis (SNA) of educational forums has shown that active participation in asynchronous discussions is positively correlated with both academic performance and student engagement. Veletsianos and Navarrete (2012) discovered that students who were central within their interaction networks were more likely to achieve academic excellence. SNA metrics, such as centrality and density, have proven to be powerful predictors of student success by revealing interaction patterns that traditional engagement metrics may overlook (Dawson, 2008b; De Laat, Lally, Lipponen, Simons, et al., 2007a). Erlin, Yusof, and Abdul Rahman (2009) demonstrated that SNA could identify key actors within discussion forums, providing educators with valuable insights into the communication structures that facilitate learning. Additionally, Suraj and Roshni (2015) illustrated that SNA could help pinpoint both active contributors and isolated students, enabling targeted interventions to enhance collaboration.

II.3. Team-Based Learning in ODFs

In team-based learning, students engage in frequent interactions, offering mutual support and feedback. Asynchronous forums enhance this process by allowing students to participate in discussions at their convenience, thereby fostering inclusive engagement. This collaborative approach is particularly effective in student-centered learning environments, as it encourages students to take an active role in their education by engaging substantively with their peers. (James et al., 2019).

II.4. Learning Analytics (LA) and Student Engagement

Learning analytics refers to the systematic process of measuring, collecting, analyzing, and reporting data concerning learners and their contexts, with the aim of comprehending and enhancing both the learning process and the environments in which it takes place (Chounta et al., 2017). As an educational tool, Learning Analytics (LA) utilizes data from various learning platforms to monitor and support student progress. By integrating LA with Social Network Analysis (SNA), educators can gain insights into participation levels, identify isolated students, and develop tailored interventions to enhance learning outcomes. (Chounta et al., 2017). For example, LA can assist instructors in identifying students who may require additional support and encouragement in their interactions.

II.5. LA and Educational Data Mining of Online Forums

In the domains of Learning Analytics (LA) and Educational Data Mining (EDM), researchers have utilized data from online forums to identify factors that facilitate meaningful student interactions and promote effective learning practices. Chounta et al. (2017) underscored the significance of LA in revealing behaviors associated with higher student engagement, which can inform instructional decisions. Specifically, da Silva, Barbosa, and Gomes (2019) applied LA to asynchronous forums, discovering that participation metrics based on message frequency and thematic analysis could predict course performance. Yang and Tang (Yang et al., 2003) also emphasized the potential of integrating LA with Social Network Analysis (SNA), demonstrating how online interactions provide valuable data for understanding student learning trajectories. By leveraging tools like Canvas and WhatsApp, LA and EDM enable educators to

analyze digital footprints, offering insights that extend beyond mere attendance or submission records.

II.6. Canvas Learning Management System and Forum

Canvas is a widely utilized Learning Management System (LMS) designed to support interactive and flexible online learning environments. Its comprehensive tools enable educators to manage course materials, monitor student progress, and facilitate communication through integrated discussion forums. Canvas has been recognized for its user-friendliness, with studies highlighting its structured and efficient platform that allows both educators and students to engage with course content and collaborate in a centralized online space (John Ryan, 2021). Recent usability evaluations have rated Canvas favorably compared to other popular LMS platforms, demonstrating that its intuitive interface and extensive features make it a reliable choice for institutions aiming to enhance their digital learning environments (Gumasing et al., 2023a). Canvas discussion forums, in particular, provide a formalized setting where students can exchange ideas, participate in structured conversations, and receive timely feedback from instructors, thereby fostering an active learning community.

II.7. WhatsApp as an Informal Learning Tool in Education

WhatsApp has emerged as a significant social media platform for informal learning in education, owing to its accessibility, ease of use, and widespread popularity among students. As a communication tool, WhatsApp enables real-time interaction, allowing students to connect with peers and instructors outside of formal classroom settings. Research has demonstrated that WhatsApp effectively promotes collaborative learning and active engagement by providing a space for sharing resources, discussing coursework, and receiving support from classmates (Dahdal, 2020a; Qamar, 2019). Furthermore, WhatsApp groups function as informal forums where students feel more comfortable discussing educational content in a less structured environment compared to traditional LMS forums. This informality fosters a sense of community and peer support, as students can quickly ask questions, clarify doubts, and reinforce their understanding of course material (Gawade et al., 2023; Najafi & Tridane, 2016b). Through its informal yet impactful presence in education, WhatsApp enhances communication and complements formal learning platforms, enabling students to engage in continuous learning across digital spaces.

II.8. Learning Theories

Three fundamental learning theories are especially pertinent to this investigation.

A. Constructivism

This theory posits that learning is an active process where students construct knowledge through interactions with others and the environment. These interactions occur online through discussion forums and messaging platforms (Erlin et al., 2009; Suraj & Roshni, 2015). Constructivism is a foundational theory in education that emphasizes learning as an active process where individuals build knowledge through their experiences, interactions with others, and engagement with the environment (Piaget, 1970; Vygotsky & Cole, 1978). In this framework, learners are not passive recipients of information but active participants who create meaning based on their social and contextual experiences. Within online learning environments, constructivism is particularly relevant, as platforms like discussion forums and messaging applications provide opportunities for learners to interact with peers, instructors, and digital content. These platforms enable learners to engage in reflective dialogue, collaborate on problem-solving tasks, and co-construct knowledge in a shared virtual space (Anderson & Dron, 2011; Reigeluth, 1999). For example, structured discussions on Learning Management Systems (LMS) like Canvas allow for formal, task-oriented interactions that align with the principles of constructivism, fostering deeper engagement with academic content. Conversely, informal platforms such as WhatsApp facilitate spontaneous and peer-driven exchanges, where learners can test ideas, seek clarification, and connect their learning to real-world contexts (Kim et al., 2021; Qamar, 2019). Additionally, the integration of multimedia resources within LMS platforms can further enhance the learning experience by providing diverse and interactive content. Moreover, the use of analytics within these systems can offer valuable insights into learner behavior and performance, enabling educators to tailor their instructional strategies accordingly.

B. Motivational Theories

Motivation is crucial in online learning environments, where students must self-regulate and engage with course material without the structure of in-person classes. The social aspects of platforms like WhatsApp can foster peer support and engagement, thereby enhancing

motivation (Suraj & Roshni, 2015; Yang et al., 2003). Motivational theories are essential for understanding student engagement in online learning settings, where learners often lack the structure and immediate feedback of traditional, in-person classes. According to self-determination theory (Deci & Ryan, 2013), motivation is enhanced when students experience autonomy, competence, and relatedness. These factors are particularly relevant in asynchronous online learning contexts, where students must self-regulate and manage their engagement with course materials. Platforms like WhatsApp can address the need for relatedness by fostering peer support and social interaction, creating a sense of community that enhances intrinsic motivation. By integrating these motivational insights, educators can design online learning experiences that encourage sustained engagement and participation. Furthermore, the use of such platforms can bridge the gap between formal and informal learning environments, providing a seamless transition for learners. This holistic approach not only supports academic achievement but also promotes the development of essential social and emotional skills.

C. Connectivism

This theory highlights the significance of technology and networks in the learning process. Students create knowledge networks through their interactions, facilitating the flow of information between individuals and transforming learning into a shared, networked activity (da Silva et al., 2019; Suraj & Roshni, 2015). Unlike traditional learning theories that emphasize individual cognition (e.g., behaviorism, constructivism), connectivist learning occurs through connections between nodes, which can include people, information sources, digital tools, and organizations (Siemens, 2005). In connectivist learning environments, knowledge is distributed across a network, making the ability to navigate, access, and synthesize this distributed knowledge a critical skill. The theory underscores the importance of digital platforms such as online forums and messaging tools, where learners engage in collaborative knowledge construction and real-time idea exchange (Downes, 2012). This theory closely aligns with contemporary educational practices that integrate technology to create participatory, learner-driven networks.

II.9. Theoretical Framework

Integrating Constructivism, Motivational Theories, and Connectivism with Learning Analytics and Social Network Analysis (SNA) establishes a comprehensive theoretical framework for

examining the correlation between student interactions and academic achievement (da Silva et al., 2019; Dawson, 2008b; Erlin et al., 2009; Suraj & Roshni, 2015). This integration allows for a multifaceted analysis that considers both the cognitive and social dimensions of learning. Additionally, it provides educators with actionable insights to design interventions that enhance student engagement and performance.

Research Questions

This study explores the following research questions:

1. What are the differences in interaction patterns between Canvas and WhatsApp, and how do these differences impact student learning?
2. Which Social Network Analysis (SNA) metrics exhibit the strongest correlation with academic performance on each platform?
3. How can educators leverage insights from SNA and Learning Analytics (LA) to create interventions that enhance student engagement and academic success?

III. Methodology

The research utilizes a Mixed Methods methodology, integrating both qualitative and quantitative data to achieve a thorough comprehension of student interactions within an asynchronous online setting. The qualitative aspect of the study entails conducting thematic content analysis on conversations from both Canvas and WhatsApp, facilitating the identification and examination of emerging themes and patterns in student communication (Creswell & Clark, 2017). In quantitative terms, Social Network Analysis (SNA) is employed to chart and assess the configuration of student interactions. This approach provides valuable insights into the frequency, centrality, and connectivity of individuals within these digital learning environments (Johnson & Onwuegbuzie, 2004a). The incorporation of these methodologies facilitates a more sophisticated analysis, encompassing both the intricacies of student discussions and the overarching interactional patterns present across various online platforms.

The course was structured using a Team-Based Learning approach, incorporating elements of the flipped classroom model. It was administered both synchronously and asynchronously via the Canvas Learning Management System (LMS). The assessment structure comprised Test I, accounting for 20% of the course weight, Test II, also at 20%, a Project at 10%, and the Final Examination at 50%. The cumulative score was 100%, with letter grades assigned based on this total. A preliminary Item Analysis of one of the tests was done and discussed with the course lecturer. This ensured that the tests were not too easy for students to pass.

3.1. Recruitment and Consent

Participants were enlisted from a Pathophysiology course within the College of Health Sciences at the University of Technology, Jamaica. This course was conducted during the autumn semester of 2022. Informed consent was secured from all students, allowing their discussions on Canvas forums and the course-specific WhatsApp group to be utilized for research purposes. All data were anonymized to uphold ethical standards and safeguard student privacy.

The General Data Protection Regulation (GDPR) was elucidated to the participants, and they were provided with the option to withdraw from the research both prior to participation and upon the conclusion of data analysis (Intouch & 2018, n.d.).

3.2. Participants

The study comprised 15 participants, of whom 10 were female and 5 were male. The research sample comprised all individuals registered in the designated health science course. Throughout the semester, data were gathered from interactions on the Canvas forum and the WhatsApp group chat, encompassing the entirety of student communications.

3.3. Data Collection

Data were retrieved and preserved in anonymized CSV files, encompassing all entries from Canvas forums and communications from the WhatsApp group chat. This systematic method enabled comprehensive thematic and network analyses.

3.4. Data Analysis

Thematic Analysis of Conversations and Visualization of Social Networks Using the R Programme with the SNA Package.

- A. WhatsApp Messages: A thematic analysis was performed to discern recurring patterns within the WhatsApp conversations. Prominent themes encompassed study-related inquiries, peer support, and non-academic discussions. The analysis of word frequencies and key phrases was utilized to determine the primary focus of the interactions.
- B. Canvas Forum Posts: Likewise, Canvas forum posts were scrutinized for thematic content pertaining to course material, peer discussions, and teacher-student interactions. Comparative thematic analyses were conducted between Canvas and WhatsApp to explore variations in the focus and structure of the interactions.

3.5. CSV Data Creation

- i. All conversation data from WhatsApp and Canvas were aggregated into CSV files, which included thematic categories, word frequencies, and message counts for each student. This dataset facilitated a structured analysis of student contributions and engagement patterns.
- ii. Social Network Analysis (SNA)
 - A. Network Mapping: Utilizing Social Network Analysis (SNA), a network map of student interactions was developed for both WhatsApp and Canvas platforms. This map depicted the connections among students, enabling both visual and quantitative evaluation of engagement.
 - B. Centrality and Density Metrics: The analysis incorporated essential Social Network Analysis (SNA) metrics, including degree centrality (the number of direct connections a student possesses), betweenness centrality (the degree to which a student serves as a bridge between others), and network density (the overall connectivity within the network). Additionally, clustering analysis was conducted to identify groups of students with frequent interactions, thereby highlighting potential collaboration clusters and isolated individuals.

3.6. Pass/Fail Comparison Table

A conclusive table was created to juxtapose each student's engagement on Canvas and WhatsApp with their course outcomes (pass or fail).

IV. Results

Table I. Demographic data - Gender, Status, and Course Success
(Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

| Gender | Status (Full or part time) | Final grade (Pass/Fail) |
|-------------|----------------------------|-------------------------|
| Female n=10 | Part-time n=0 | Fail n=0 |
| Male n=5 | Full-time n=15 | Pass n=15 |

Table I presents the demographic and academic outcomes of the study participants (N = 15). Among them, 10 participants identified as female and 5 as male. All participants were enrolled as full-time students. Upon completion of the course, all students successfully passed, with no recorded failures (n = 0 pass, n = 15 fail).

Table II outlines the progression of topics and themes as they emerged throughout the course, shaped by the instructor's guidance and the participants' engagement. The initial two topics of the course were introduced by the instructor via both the Canvas Forum and a WhatsApp group. Student responses on Canvas were characterized by formal language and closely aligned with the designated topics and lecture materials. In contrast, discussions on WhatsApp were more dynamic and contextual, often incorporating real-life examples drawn from personal, familial, or professional experiences. Notably, while discussions on Canvas typically concluded following the contributions of most students, conversations on WhatsApp frequently extended over several days, reflecting a more sustained and informal engagement with the course content.

Table II. Canvas and Whatsapp Themes/ Discussion
(Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

| Teacher/Students | Topics/ Theme | |
|------------------|--|---|
| | Canvas | WhatsApp |
| Teacher | Cell injury | Cell Injury |
| Students | Damage to cell (reflecting the lecture) | Damage to cell (burns from cooking, riding a motorcycle) Chemical burn to skin and hair. |
| Teacher | Chromosomal disorders | Chromosomal disorders |
| Students | Answers based on lecture eg. Down Syndrome. Answers mirrored the lecture discussion. | Discussion around real cases, personal experience, and the sign and symptoms they remembered. Less structured, high more engagement |

Figure 1 illustrates the interaction network among students, with node sizes reflecting each individual's degree centrality. In this visualization, larger nodes indicate students who exhibit a higher number of direct connections within the network, signifying greater centrality and engagement in peer interactions.

The computed values for both degree centrality and betweenness centrality for each student are presented. Furthermore, the overall network density is approximately 0.19, suggesting that about 19% of all possible student-to-student connections are realized within the interaction network.

IV.1. Social Network Analysis

Several key factors must be considered when interpreting the Social Network Analysis (SNA) of interactions on Canvas and WhatsApp.

IV.1.1. Network Density

WhatsApp (Network Density ≈ 0.28): The relatively high network density indicates that a substantial proportion of potential connections among students are active, reflecting frequent and widespread interaction. This suggests that communication within the WhatsApp group is more evenly distributed, with students engaging with a broad range of peers. Such a pattern is indicative of a collaborative and informal communication environment, where peer-to-peer exchanges are prevalent and information circulates more freely throughout the network.

Canvas (Network Density ≈ 0.19): The lower density observed in the Canvas interaction network suggests a more limited number of connections among students compared to WhatsApp. This pattern reflects a tendency toward more selective and structured engagement, likely confined to mandatory tasks or discussion prompts. Interactions on Canvas appear to be more formal and focused, with students typically responding to specific threads or a limited number of peers. Such interaction dynamics may constrain opportunities for spontaneous collaboration and broader peer-to-peer communication.

The comparatively higher network density observed in WhatsApp reflects more frequent and broadly distributed interactions among students, indicating its effectiveness in facilitating informal peer engagement. Conversely, the lower density in Canvas may suggest a more concentrated and purposeful mode of communication, potentially supporting deeper, task-oriented discussions within a structured academic context.

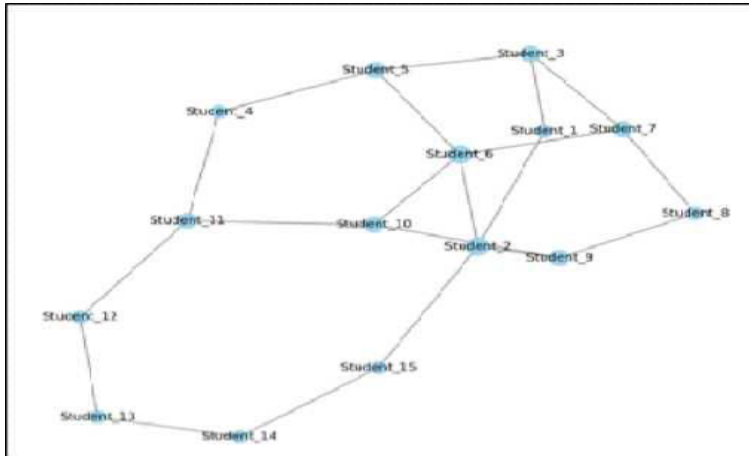


Fig. 1 Graph: Canvas – Nodes size represents the degree of centrality (copyright IEEE)

Table III. Degree of Centrality and Betweenness in Canvas (Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

| Student | Degree Centrality | Student | Betweenness Centrality |
|------------|-------------------|------------|------------------------|
| Student_1 | 0.14 | Student_1 | 0.04 |
| Student_2 | 0.29 | Student_2 | 0.30 |
| Student_3 | 0.21 | Student_3 | 0.07 |
| Student_4 | 0.14 | Student_4 | 0.067 |
| Student_5 | 0.21 | Student_5 | 0.12 |
| Student_6 | 0.29 | Student_6 | 0.22 |
| Student_7 | 0.21 | Student_7 | 0.06 |
| Student_8 | 0.14 | Student_8 | 0.02 |
| Student_9 | 0.21 | Student_9 | 0.13 |
| Student_10 | 0.21 | Student_10 | 0.17 |
| Student_11 | 0.21 | Student_11 | 0.20 |
| Student_12 | 0.14 | Student_12 | 0.10 |
| Student_13 | 0.14 | Student_13 | 0.06 |
| Student_14 | 0.14 | Student_14 | 0.08 |
| Student_15 | 0.14 | Student_15 | 0.15 |

IV.1.2. Degree Centrality

Within the WhatsApp interaction network, elevated degree centrality values indicate that a substantial number of students are highly active and maintain numerous connections. This pattern reflects broad engagement across the group, suggesting that WhatsApp serves as an

effective platform for fostering widespread participation and peer support. The presence of multiple communication hubs—students exhibiting high degree centrality—further implies that information circulates rapidly and efficiently within the network. Refer to Figure 2 for a visual representation.

In contrast, the Canvas interaction network tends to exhibit fewer students with exceptionally high degree centrality, reflecting the platform's emphasis on structured and task-specific participation rather than widespread peer interaction. Students with elevated centrality in this context are likely to dominate particular discussion threads, while overall engagement remains more limited outside these formalized settings. Refer to Figure 1 for a visual depiction.

A higher degree of centrality within the WhatsApp network indicates a more evenly distributed and less hierarchical pattern of interaction, suggesting that participation is more balanced among students. In contrast, the Canvas network tends to feature a smaller number of highly central participants who dominate discussions, reflecting a more structured and potentially restrictive communication environment. This comparison implies that WhatsApp supports more egalitarian and spontaneous peer engagement, whereas Canvas facilitates more focused and directive interactions.

IV.1.3. Betweenness Centrality

In the WhatsApp network, elevated betweenness centrality values indicate that certain students function as critical intermediaries, facilitating connections between otherwise separate subgroups. These individuals play a pivotal role in maintaining the cohesion of the network by enabling the flow of information across different segments. However, due to the decentralized nature of WhatsApp interactions, this bridging function is often distributed among multiple participants, promoting fluid and inclusive communication. Refer to Table IV for detailed metrics.

In the Canvas network, betweenness centrality tends to be concentrated among a limited number of participants, often including instructors or moderators, who serve as primary connectors between distinct student clusters. This hierarchical configuration suggests a more controlled flow of information, with key individuals guiding and structuring the discourse. Such a pattern reflects a centralized communication model, where interaction is mediated through a few influential nodes. Refer to Table IV for detailed centrality metrics.

A greater number of students exhibiting high betweenness centrality within the WhatsApp network indicates a more collaborative communication structure, wherein multiple participants actively facilitate the exchange of information across subgroups. In contrast, the Canvas network tends to be characterized by a smaller set of central figures—often including

instructors—who predominantly manage or moderate the flow of interaction. This suggests a more structured and instructor-led communication environment.

Figure 2 presents a visualization of the WhatsApp interaction network, with node sizes proportional to each student's degree centrality—that is, the number of direct connections they maintain within the network. Larger nodes signify students who are more extensively connected, indicating a higher level of interaction with peers.

The WhatsApp interaction network exhibits a density of approximately 0.28, which is notably higher than that of the previously analyzed network. This elevated density indicates a greater frequency of interactions among students, suggesting a more interconnected and actively engaged communication environment.

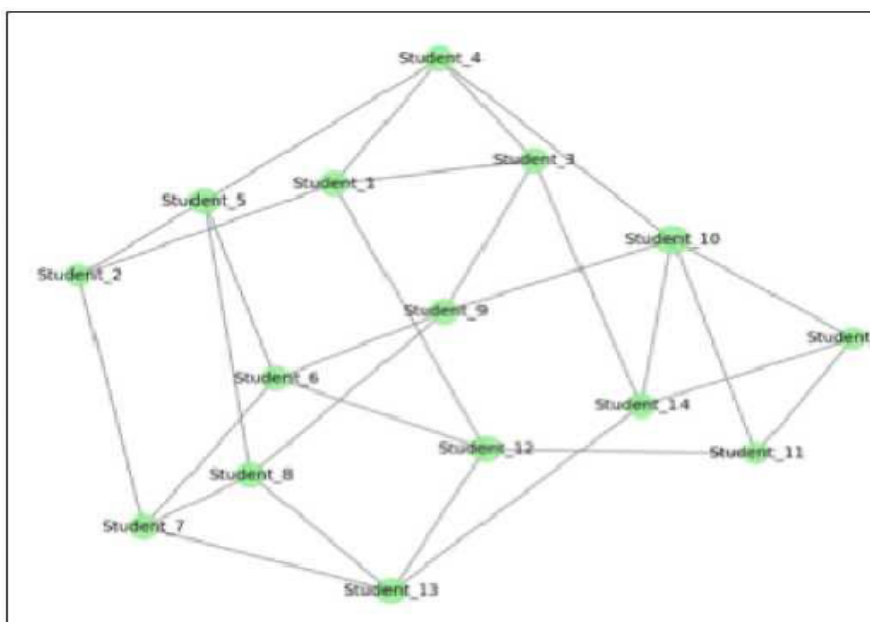


Fig. 2 Graph: WhatsApp – Nodes size represents the degree of centrality
(Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

IV.1.4. Interaction Type and Frequency

On WhatsApp, student interactions tend to be more frequent and informal, often giving rise to spontaneous and wide-ranging discussions. This mode of communication typically encompasses both academic and non-academic content, contributing to the development of a community-oriented environment. However, the informal and unstructured nature of these exchanges may limit the depth and focus of discussions when compared to more structured platforms such as Canvas.

Interactions on Canvas are generally more formal and structured, typically organized around specific tasks or discussion prompts. As participation is often mandatory, student contributions

tend to be more academically focused, promoting deeper engagement with course content. However, this structured format may result in a lower overall volume of interaction compared to more informal platforms.

The increased frequency and informal nature of interactions on WhatsApp suggest that it is particularly effective in promoting peer support and facilitating real-time collaboration. However, such discussions may lack a strong academic focus. In contrast, Canvas supports more in-depth, academically oriented discourse, though its structured format may constrain overall participation and limit opportunities for spontaneous peer-to-peer engagement.

Table IV. Degree of Centrality and Betweenness in WhatsApp
(Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

| Student | Degree Centrality | Student | Betweenness Centrality |
|------------|-------------------|------------|------------------------|
| Student_1 | 0.29 | Student_1 | 0.09 |
| Student_3 | 0.29 | Student_3 | 0.06 |
| Student_2 | 0.21 | Student_2 | 0.03 |
| Student_4 | 0.29 | Student_4 | 0.09 |
| Student_5 | 0.29 | Student_5 | 0.07 |
| Student_6 | 0.29 | Student_6 | 0.07 |
| Student_7 | 0.29 | Student_7 | 0.05 |
| Student_8 | 0.29 | Student_8 | 0.06 |
| Student_9 | 0.29 | Student_9 | 0.09 |
| Student_10 | 0.36 | Student_10 | 0.12 |
| Student_11 | 0.21 | Student_11 | 0.03 |
| Student_12 | 0.29 | Student_12 | 0.11 |
| Student_13 | 0.29 | Student_13 | 0.10 |
| Student_14 | 0.29 | Student_14 | 0.09 |
| Student_15 | 0.21 | Student_15 | 0.01 |

The interpretation of the results is summarized below.

The elevated levels of network density, degree centrality, and betweenness centrality observed in the WhatsApp network indicate a highly collaborative and peer-driven communication environment, characterized by frequent and widespread student interaction. This suggests that WhatsApp is particularly effective in facilitating peer support and fostering a sense of community within the learning context. However, the informal and decentralized nature of these interactions may limit the depth of academic engagement when compared to more structured platforms such as Canvas.

The lower network density and more selective interaction patterns observed on Canvas suggest that the platform is more conducive to structured academic discourse, where students engage in focused and in-depth discussions related to course content, albeit with fewer overall connections. The presence of key intermediaries, such as instructors, indicates a more centralized and controlled communication flow, which may help maintain academic rigor but could also constrain broader peer-to-peer collaboration.

Table V. Students' Interaction on Canvas Forum and WhatsApp Group Chat.

(Duluten, S., Grannum, J., Hill-Berry, N.P, 2024; Copyright IEEE)

| Canvas Source | Canvas Target | Canvas Weight | Whats- App Source | Whats- App Target | Whats- App Weight |
|---------------|---------------|---------------|-------------------|-------------------|-------------------|
| Student_1 | Student_2 | 3 | Student_1 | Student_3 | 5 |
| Student_3 | Student_1 | 2 | Student_2 | Student_4 | 4 |
| Student_4 | Student_5 | 1 | Student_3 | Student_5 | 6 |
| Student_6 | Student_2 | 1 | Student_4 | Student_6 | 3 |
| Student_7 | Student_3 | 4 | Student_5 | Student_7 | 5 |
| Student_5 | Student_6 | 2 | Student_6 | Student_8 | 4 |
| Student_8 | Student_7 | 1 | Student_7 | Student_9 | 7 |
| Student_9 | Student_8 | 1 | Student_8 | Student_10 | 3 |
| Student_10 | Student_9 | 2 | Student_9 | Student_11 | 5 |
| Student_11 | Student_10 | 1 | Student_10 | Student_12 | 4 |
| Student_12 | Student_11 | 1 | Student_11 | Student_13 | 3 |
| Student_13 | Student_12 | 1 | Student_12 | Student_14 | 5 |
| Student_14 | Student_13 | 2 | Student_13 | Student_15 | 4 |
| Student_15 | Student_14 | 3 | Student_14 | Student_1 | 6 |
| Student_2 | Student_15 | 1 | Student_15 | Student_2 | 4 |
| Student_3 | Student_5 | 2 | Student_2 | Student_5 | 2 |
| Student_6 | Student_7 | 1 | Student_4 | Student_7 | 6 |
| Student_9 | Student_2 | 3 | Student_6 | Student_9 | 5 |
| Student_10 | Student_6 | 2 | Student_8 | Student_11 | 7 |
| Student_11 | Student_4 | 1 | Student_10 | Student_13 | 6 |

Table V presents data on all students who engaged on both platforms, with interaction weights representing the frequency or intensity of their communications.

V. Discussion

The discussion section interprets the findings within the broader context of learning. To effectively engage educators with insights from this case study, each research question will be systematically addressed, with particular emphasis on the implications of the results for teaching and learning practices. The discussion begins by revisiting the first research question.

What are the differences in interaction patterns between Canvas and WhatsApp, and how do these differences impact student learning?

In order to address this research question, the Social Network Analysis (SNA) findings from both WhatsApp and Canvas offer meaningful insights into the distinct interaction patterns and learning dynamics fostered by each platform. The results reveal that WhatsApp, characterized by a higher network density (approximately 0.28) and elevated degree centrality, facilitates frequent and widespread student interactions. This suggests a more collaborative and interconnected learning environment. These findings are consistent with prior research indicating that informal communication tools such as WhatsApp are effective in promoting rapid information exchange, peer bonding, and mutual support, particularly in less formal educational contexts (Lin et al., 2019; Taylor-Jackson et al., 2021). Such platforms are well-suited for addressing quick queries, enabling collaborative assistance, and supporting spontaneous dialogue, thereby reflecting a peer-driven and informal mode of learning.

In contrast, the Canvas platform exhibits a lower network density (approximately 0.19) and is characterized by more selective, task-specific interactions. Canvas promotes structured, content-driven engagement, often facilitated by instructors or highly active students who serve as central figures in guiding discussions. This interaction pattern aligns with existing research indicating that formal learning management systems (LMS) support deeper engagement with academic content, shaped by the structured and goal-oriented nature of the platform (Kassens-Noor et al., 2019a; Tessier, 2022).

Implication for Educators:

WhatsApp may be effectively utilized as a peer-support mechanism to facilitate collaborative and informal learning. It provides a platform through which students can participate in group activities, coordinate study sessions, and seek prompt clarification on course-related queries.

Canvas should be utilized to facilitate structured academic discourse. Instructors can enhance the platform's effectiveness by designing clear, academically oriented prompts and fostering deeper, task-specific engagement among students.

To interpret the findings related to Social Network Analysis (SNA) metrics, we now turn to the second research question.

Which Social Network Analysis (SNA) metrics exhibit the strongest correlation with academic performance on each platform?

In addressing this research question, the analysis of Social Network Analysis (SNA) metrics reveals that certain students occupy central roles across both platforms, either through high degree centrality—indicating frequent interactions with a wide range of peers—or high betweenness centrality—signifying their function as connectors between distinct subgroups. Within the WhatsApp network, the decentralized and peer-driven nature of communication results in multiple students serving as key hubs, thereby facilitating widespread peer support and a more balanced distribution of interactions (Selwyn & Stirling, 2016). This pattern aligns with existing literature suggesting that informal communication networks contribute to relationship-building and the development of collaborative competencies, both of which are essential for academic success (Tang & Hew, 2019).

Within the Canvas learning management system, high-centrality roles are typically occupied by instructors or particularly active students, resulting in a communication structure that is both centralized and academically oriented. This configuration fosters a more controlled environment in which key individuals facilitate discourse and guide the flow of information. Prior research indicates that the presence of instructors and the emergence of student leaders in such structured digital environments can significantly enhance the quality and depth of learning interactions, thereby positively influencing student achievement (Garrison, 2018; Mahmud et al., 2022).

Implication for Educators:

Social network analysis (SNA) can serve as a valuable tool for educators seeking to identify students who exhibit high levels of degree and betweenness centrality, as these individuals often function as influential connectors within learning communities. By recognizing and encouraging these students to assume peer leadership roles, educators can enhance overall engagement, particularly among less active participants. This approach aligns with research suggesting that SNA metrics can effectively highlight potential leaders within educational settings, although complementary methods may also be necessary to ensure comprehensive identification (Knaub et al., 2018).

Educators can leverage social network analysis to identify students who appear socially isolated or exhibit low levels of engagement. By facilitating connections between these

students and peer leaders, or by offering targeted support, educators may enhance participation and foster improved academic outcomes. Research indicates that structured peer interaction can significantly contribute to learning, particularly when students are encouraged to collaborate and reach consensus during educational tasks (Tenenbaum et al., 2019).

The concluding inquiry guiding our case study was formulated as follows:

How can educators leverage insights from SNA and Learning Analytics (LA) to create interventions that enhance student engagement and academic success?

The analysis revealed distinct patterns of interaction across WhatsApp and Canvas, suggesting that each platform fulfills unique educational functions (Selwyn & Stirling, 2016). WhatsApp appears to support informal, collaborative learning environments, making it particularly effective for activities that demand frequent communication, rapid idea generation, or coordination among peers, such as group assignments. In contrast, Canvas is more conducive to structured academic engagement, especially in contexts that prioritize depth of thought and formal assessment, such as graded discussions. These findings are consistent with prior research indicating that the nature of digital platforms significantly influences student engagement and academic performance, depending on the type of interaction they promote (Barton et al., 2021; Panagopoulos et al., 2023).

Implication for Educators:

A strategic integration of digital platforms can enhance the learning experience by leveraging the unique affordances of each. Educators may assign informal, collaborative activities—such as peer discussions or group coordination—to platforms like WhatsApp, which support real-time, conversational interaction. Conversely, more formal and academically rigorous tasks, including structured discussions and graded assignments, are better suited to platforms like Canvas. This blended approach enables a more holistic educational environment that accommodates diverse learning needs and communication styles.

By leveraging insights derived from social network analysis (SNA), educators can systematically monitor patterns of student engagement throughout a course. This approach enables the identification of both highly active participants and those who may be at risk of disengagement. Such continuous monitoring facilitates timely, data-informed interventions, allowing instructors to adapt pedagogical strategies in real time to better support student learning and enhance overall academic outcomes.

V.1. Using Learning Analytics for Intervention and Feedback

This study extends its implications to practical applications, particularly in the context of instructional interventions and feedback mechanisms. Integrating social network analysis (SNA) within the broader framework of learning analytics (LA) provides educators with actionable insights into student engagement dynamics. Through the real-time analysis of interaction patterns, instructors can deliver timely feedback and implement targeted interventions to enhance the learning experience. For instance, identifying peripheral or isolated students in Canvas discussions enables instructors to promote their participation, while recognizing central figures in WhatsApp networks allows for the strategic encouragement of peer support. Empirical evidence supports the use of LA-driven interventions to foster increased engagement and improved academic performance (Gašević et al., 2019; Hwee et al., 2020).

Social network analysis (SNA) can inform instructional design by enabling educators to scaffold learning activities that promote inclusive participation. For example, collaborative tasks can be assigned through platforms like WhatsApp to foster informal peer interaction, while more reflective and independent assignments can be facilitated via Canvas to encourage deeper academic engagement. This progression supports students in transitioning from social collaboration to more cognitively demanding tasks (Pedaste et al., 2015).

Additionally, SNA metrics serve as valuable tools for formative assessment by offering insights into the nature and extent of student interactions. These insights can help instructors identify learners who may benefit from additional support, as well as those who demonstrate leadership potential and could be positioned for mentorship roles in future learning contexts.

V.2. Implications for Practice Guided by the Findings

Employing Social Network Analysis (SNA) as a component of Learning Analytics (LA) within both formal (e.g., Canvas) and informal (e.g., WhatsApp) learning environments yields valuable insights into student engagement and academic performance. By mapping central actors, identifying interaction clusters, and analyzing engagement patterns, SNA offers a data-informed framework that enables educators to more effectively support student learning. The following points outline key implications for educational practice based on these findings:

V.2.1. SNA as a Learning Analytics (LA) Tool

As a component of Learning Analytics (LA), Social Network Analysis (SNA) offers a more nuanced understanding of student behavior than traditional metrics such as attendance or assignment completion. Rather than focusing solely on participation counts, SNA enables educators to examine the structure and quality of student interactions, including patterns of

connectivity, engagement, and the flow of information within learning communities. For example, SNA can identify students who occupy influential positions within the network—those with high degree and betweenness centrality—as well as those who are socially peripheral and may benefit from targeted instructional support (Dawson, 2008a; Topali et al., 2023).

Educators can apply these insights in several practical ways:

- Recognizing peer leaders and knowledge brokers within the learning network, and encouraging them to support their classmates, thereby promoting a more collaborative and interactive learning environment.
- Identifying students who are socially isolated or minimally connected, and providing them with targeted support or integrating them into group-based activities to enhance their engagement and sense of belonging in the course.

Practical Implication: Social Network Analysis (SNA) equips educators with the ability to tailor interventions based on patterns of student interaction, ultimately contributing to a more inclusive and supportive online learning experience.

V.2.2. Formal Discussion Forums (Canvas)

Formal learning platforms such as Canvas offer a structured setting in which students engage with course content, typically guided by instructor-generated prompts. Social Network Analysis (SNA) applied within these environments reveals how student roles and interaction patterns shape the dynamics of structured discussions.

- Students with high centrality in Canvas discussions often function as key nodes within the network, influencing the flow of information and peer learning. Actively encouraging these students to participate can enhance overall engagement across the learning community (De Laat, Lally, Lipponen, Simons, et al., 2007b; Haythornthwaite & De Laat, 2010).
- Instructors can design purposeful interactions by aligning discussion prompts with core course concepts, using SNA metrics to assess participation levels, and refining prompts to promote deeper, more meaningful dialogue (Dawson, 2008a; Johnson & Onwuegbuzie, 2004b).

Practical Implication: Utilizing SNA insights in formal discussion forums enables educators to refine discussion strategies and implement targeted interventions that foster academic engagement and conceptual understanding. This approach also promotes collaborative problem-solving among students, contributing to a more interactive and effective learning environment (Rannastu-Avalos et al., 2023).

V.2.3. Informal Discussion Forums (WhatsApp)

Informal communication platforms such as WhatsApp enable spontaneous, real-time interactions, offering a flexible environment where students can pose questions, provide peer support, and clarify course-related content. When analyzed through Social Network Analysis (SNA), these platforms reveal:

- High-frequency interactions and extensive connectivity, which contribute to a strong sense of community and mutual support among students. This dynamic can help alleviate feelings of isolation and anxiety, particularly in asynchronous or hybrid learning contexts.
- The emergence of knowledge-sharing clusters, where students regularly exchange ideas, respond to inquiries, and share academic resources. By identifying these clusters through SNA, educators can promote collaborative learning and informal peer mentorship.

Practical Implication: Informal platforms like WhatsApp complement formal learning environments by fostering community-building and facilitating immediate peer-to-peer support. Educators can enhance student engagement by encouraging the use of such platforms for real-time collaboration and informal academic interaction.

V.2.4. Enhancing Student Retention and Success

The capacity of Social Network Analysis (SNA) to uncover interaction patterns linked to academic achievement holds significant potential for informing student retention strategies. By examining participation indicators—such as message frequency, response latency, and network centrality—educators can:

- Identify correlations between engagement levels and academic outcomes (e.g., pass/fail rates), enabling timely interventions for students at risk of underperformance.
- Detect engagement behaviors associated with high academic achievement, which can be promoted as effective practices across the student cohort.

Practical Implication: Integrating SNA with academic performance data allows for the development of evidence-based retention strategies, facilitating proactive and personalized support for students who may be at risk of disengagement or academic failure.

V.2.5. Supporting Team-Based Learning

Social Network Analysis (SNA) underscores the significance of team dynamics and peer support in shaping learning outcomes, offering a valuable framework for instructional design in team-based learning environments. By identifying central actors and subgroup formations within student networks, SNA enables educators to:

- Construct balanced teams by integrating students with varying levels of engagement, thereby fostering peer support and enhancing collaborative learning (Goggins et al., 2016).
- Monitor intra-team interactions and make informed adjustments to team composition or provide targeted support when engagement levels are suboptimal.

Practical Implication: Through the application of SNA, educators can design and sustain high-functioning, collaborative teams that promote equitable participation and support the achievement of collective learning objectives.

V.2.6. Informing Future Course Design

Insights derived from Social Network Analysis (SNA) of both formal and informal learning environments offer valuable guidance for future course design. By examining how structured and unstructured discussions influence student engagement and academic success, educators can:

- Enhance instructional strategies within formal platforms by designing discussion prompts and thematic content that align with core learning objectives and stimulate active participation.
- Integrate informal communication channels purposefully, creating spaces for real-time peer interaction and support, while reserving formal forums for academically rigorous, graded discussions.

Practical Implication: The integration of SNA and Learning Analytics (LA) enables the development of balanced, interactive, and supportive learning environments. This approach fosters a culture of active learning and sustained engagement, ultimately enhancing student motivation and academic achievement (Hortigüela-Alcalá et al., 2019).

V.2.7. Implication of Findings for Broader Educational Practices and Integration of Communication Tools

The findings of this study underscore the value of integrating both formal and informal communication platforms into broader pedagogical strategies to enhance student engagement and learning outcomes. Formal learning management systems (LMS), such as Canvas, offer structured, goal-oriented environments that support academically rigorous discussions aligned with course objectives. In contrast, informal tools like WhatsApp provide a flexible, peer-driven space conducive to spontaneous interaction and community building, which can support continuous learning outside formal settings.

Recognizing the distinct affordances of each platform allows educators to adopt a blended communication strategy that addresses diverse learner needs. For instance, instructors might

facilitate structured academic discourse through Canvas while simultaneously encouraging peer support and contextual dialogue via WhatsApp. This approach aligns with existing research advocating for the integration of formal LMS platforms with informal communication tools to foster more dynamic and interactive learning environments (Ch'ng & Lay, 2023; Kassens-Noor et al., 2019b).

Comparative analyses with other LMS platforms, including Blackboard and Moodle, reveal similar patterns of structured engagement, suggesting that the strategic incorporation of informal tools can universally enhance online education (Gumasing et al., 2023b). Informal platforms such as WhatsApp, Telegram, and Microsoft Teams offer accessible, real-time communication features that can promote collaboration and mitigate student isolation (Dahdal, 2020b). This integrative model supports the development of inclusive, flexible, and community-oriented learning environments, thereby enhancing adaptability and engagement across diverse student populations.

Conclusion

The results of the simulated Social Network Analysis (SNA) offer meaningful insights into how different digital platforms cultivate distinct patterns of student interaction and engagement. The analysis reveals that WhatsApp, characterized by higher network density and centrality measures, facilitates frequent and informal peer collaboration. This suggests that WhatsApp is particularly well-suited for real-time communication, peer support, and collaborative learning tasks. In contrast, Canvas supports more structured, academically focused interactions, enabling students to engage deeply with course content within a formal learning environment.

These findings highlight the pedagogical value of leveraging each platform's unique affordances to optimize learning outcomes. Educators can enhance student engagement by encouraging peer collaboration through WhatsApp while utilizing Canvas for structured, content-driven discussions. Furthermore, the application of SNA enables instructors to design more targeted and personalized interventions. By identifying central participants and less engaged students, educators can adapt their teaching strategies to promote a more inclusive and collaborative learning environment.

Integrating SNA within the broader framework of Learning Analytics (LA) also allows for the continuous monitoring of student interactions. This facilitates real-time feedback and instructional adjustments, supporting the development of student-centered learning environments that balance collaborative engagement with academic rigor.

Limitations of the Study

This study is subject to certain limitations, primarily due to its case study methodology and the relatively small sample size, which constrain the generalizability of the findings to broader educational contexts or larger student populations. While the observed trends offer valuable preliminary insights, further empirical investigation involving larger and more diverse samples is necessary to validate and extend these results. Moreover, the study's focus on two specific platforms—WhatsApp and Canvas—limits the applicability of the findings to other digital communication tools, which may yield different interaction patterns and learning outcomes.

Future Work

Future research should aim to broaden the scope of investigation by incorporating larger and more diverse participant samples, thereby enhancing the generalizability of findings across varied educational contexts. Comparative analyses involving a wider range of digital communication platforms could yield deeper insights into how different tools influence student engagement and learning outcomes. Additionally, examining the effects of targeted interventions informed by Social Network Analysis (SNA) and Learning Analytics (LA) could offer valuable contributions to understanding their impact on student success and retention. Longitudinal studies are also recommended to explore the sustained influence of platforms such as WhatsApp and Canvas on student interaction patterns and academic development over time.

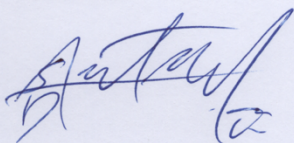
Acknowledgements

I would like to express my sincere gratitude to my family, professors, and friends for their unwavering support throughout my academic journey. I am especially grateful to both of my supervisors for their invaluable guidance, insightful feedback, and continuous encouragement during the development and writing of this thesis. I also extend my heartfelt thanks to my fellow MA peers, whose constructive critiques and thoughtful discussions greatly contributed to the refinement of my work.

Author's declaration: *I hereby declare that I have written this thesis independently and that all contributions of other authors and supporters have been referenced. The thesis has been written in accordance with the requirements for graduation theses of the Institute of Education of the University of Tartu and is in compliance with good academic practices.*

Serbest DULUTEN

31/05/2025

A handwritten signature in blue ink, appearing to read 'Serbest Duluten', written in a cursive style.

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