SOCIAL NETWORK ANALYSIS OF PROBLEM-BASED LEARNING IN MEDICAL EDUCATION

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CHAPTER I

INTRODUCTION

1.1   RESEARCH BACKGROUND

Medical education has progressively shifted away from traditional lecture-based and rote memorisation methods. Although not without benefits, these methods have been criticised for their limited capacity to engage learners meaningfully and contextually (Kaur et al., 2014). In response to the need for more effective teaching and learning strategies, Problem-Based Learning (PBL) has been widely adopted as an integrated, student-centred, and self-directed learning approach. PBL places learners in small groups where they collaboratively solve clinically and contextually relevant problems, promoting more profound understanding and critical thinking, while developing relevant clinical reasoning skills essential for medical professionals (Yoo et al., 2019).

Collaborative learning is at the core of PBL, which emphasises active participation, mutual engagement, and the sharing of knowledge among peers. Collaborative and problem-solving skills are important social skills for students to approach tasks and solving problems jointly (Hendarwati et al., 2021). This interaction-rich environment encourages students to explore and apply theoretical knowledge while developing interpersonal communication skills. In such a setting, peer assessment serves as a valuable tool to reinforce reflective practices and accountability. As part of formative assessment, feedback plays an essential role that enhances both individual and group learning.

Despite the recognised importance of collaboration in PBL, traditional assessments often fail to objectively capture the rich and diverse quality of the dynamics of group interaction. Most evaluations rely on subjective tutor impressions or limited peer feedback forms, which may not fully reflect the nuances of peer interaction and

collaboration (Jang & Park, 2016). This limitation requires a more robust analytical framework to assess and uncover collaborative behaviour systematically.

Social Network Analysis (SNA) offers a robust methodology to address this gap. By conceptualising individuals as nodes and their interaction as edges within the network, SNA enables both visualisation of interaction and quantitative analysis of such interactions (Goel & Dey, 2011). It can reveal patterns of connectivity, influence, and participation within a group. All of which are crucial in PBL setting. Although SNA has been increasingly applied in online medical education and organisational studies, the use in traditional, face-to-face education, specifically medical education, and particularly within the context of PBL, remains limited (Isba et al., 2017).

This study aims to explore the potential of SNA as a tool to evaluate collaborative interactions in non-virtual PBL sessions among medical students. Specifically, this study seeks to (1) map and analyse the social network structures within PBL groups, (2) examine the relationship between student participation (measured through network centrality) and academic performance, and (3) identify students at risk of underperformance based on the interaction patterns. By integrating SNA with peer assessment data, this study aspires to provide a deeper understanding of the social dynamics of PBL and support the development of targeted interventions.

1.2   PROBLEM STATEMENT

Despite the praise and benefits of PBLs, there exists some concerns surrounding the understanding of the nuanced interactions between peers that occur during the session. The effectiveness of PBL in medical education varies among students, with some students being more engaged than others. This variation may raise concerns for less-engaged students. Existing research suggests that collaborative work may be studied using methods such as Social Network Analysis (SNA) to analyse these interactions. By applying SNA to PBL, this study aims to explore key structural differences between multiple PBL networks and explore the relationship between peer engagement and academic performance. Additionally, this study seeks to identify network patterns associated with underperforming students, which may allow for early intervention strategies

1.3   OBJECTIVE OF RESEARCH

1.3.1   General Objective

To analyse the structural and dynamic properties of Problem-Based Learning (PBL) discussion networks and their association with student academic performance.

1.3.2   Specific Objective

To compare the structural differences and interaction dynamics across multiple PBL discussion networks.

To examine the relationship between individual centrality measures (e.g., degree, betweenness, closeness) within PBL networks and students' exam performance.

To identify distinctive network patterns and interaction characteristics associated with underperforming students in PBL discussions.

CHAPTER II

LITERATURE REVIEW

2.1   LITERATURE REVIEW

Medical education has steered away from traditional lecture-based and memorisation-based learning, which does not provide adequate prospects to the learners of the subject matter in a contextual manner (Kaur et al., 2014; Yoo et al., 2019). As such, Problem-Based Learning (PBL) was introduced as an integrated, student-centred, and self-directed mode of learning (Chegwidden, 2006). PBL is conducted in smaller groups of 5-7 students, facilitating a deeper engagement with the material by encouraging students to work collaboratively in small groups to solve clinically relevant problems under the guidance of a tutor. This method promotes student-centred active learning, where students are not passive recipients of information but rather active participants who enable them to develop contextual information. PBL/case-based learning not only leads to better learning but also improves clinical reasoning, self-directed learning skills, and motivation for learning (Hakimeh et al., 2016; Mohammed et al., 2024; Pruitt et al., 2017; Yoo et al., 2019). However, it is not without challenges and limitations. Often due to the complex nature of interaction within PBL discussions, assessment of PBL efficacy remains an issue. There is a gap of research on factors that contribute to successful collaborative work in PBLs such as interdependence, which is crucial as the success of PBL depends on how well individual students work together (Jang & Park, 2016). PBL represents a significant advancement in medical education, addressing the limitations of traditional teaching methods by fostering a more engaging and effective learning environment. Nonetheless, due to PBL's collaborative nature, assessing student interactions and contributions within groups becomes essential to fully understanding and supporting this learning methodology.

Peer assessment is typically used in evaluating presentations and practicals (Centre et al., 2004). Peer assessment can be utilised at different stages throughout the learning process, offering ongoing practice for those conducting the assessments and delivering

feedback on progress to those being assessed (Alias et al., 2015). Many parameters encapsulate the concept of peer interaction in PBL, such as Attitude and Collaborative Work, as evaluated by Elizondo-Montemayor (2004) (Elizondo-Montemayor, 2004). However, this paper aims to highlight one of the components: collaborative work. Collaborative work and PBL are interconnected pedagogical approaches emphasising interactive and student-centred learning experiences. In collaborative learning, knowledge and expertise are shared among students in small groups, similar to PBL. This promotes deep learning when students are engaged in high-quality social interaction, such as discussing contradictory information (Scager et al., 2017). Integrating collaborative learning and the PBL framework appears to yield significant results. A study by Hendarwati et al. (2021) implemented an integration of collaborative learning and PBL called Collaborative Problem Based Learning (CPBL), which has been shown to increase student collaborative and problem-solving skills (Hendarwati et al., 2021). Thus, this study aims to utilise collaborative work in PBL to assess peer assessment for network development. An objective and systematic approach is required to effectively evaluate the quality and structure of the nuanced collaborative interactions within PBL groups.

Social Network Analysis (SNA) is a methodological approach to examining human relationships and structures within social networks. It uses graph theory to represent individuals as nodes and their interactions as edges. Thus, for this study, the students will be represented by nodes, and edges will represent the collaborative work interaction. This analytical framework allows researchers to explore the dynamics of social relationships across various contexts, from informal social media interactions to formal organisational structures. SNA has gained prominence as it provides insights into the underlying connectivity patterns and influence among nodes within a network, thereby facilitating a deeper understanding of social dynamics (Goel & Dey, 2011; Samatan et al., 2020). SNA has emerged as a powerful methodological tool for studying the dynamics of PBL in educational settings, particularly in medical education. SNA provides a framework for understanding the relational aspects of learning environments by mapping interactions among participants, thus revealing the underlying structures that influence group dynamics and learning outcomes. This approach is particularly relevant in PBL contexts, where collaboration and communication are essential for

effective problem-solving and knowledge construction (Saqr et al., 2019; Saqr et al., 2020). Several studies have demonstrated how SNA can be applied to uncover meaningful patterns in student engagement and academic performance across diverse educational context not limited to medical education.

A study by Dokuka et al. (2020) found that the diffusion of academic achievement can be determined by the nature of the social network. Their findings showed that higher academic performance is positively associated with social integration in the classroom, emphasising the importance of close friendship relationships that effectively spread complex behaviours such as academic achievement (Dokuka et al., 2020). Similarly, Castillo et al. (2021), who conducted a study on group work among civil engineering students, found that closely connected groups and triads within the network are related to lower grades. They were able to establish the relationship between the social characteristics of individuals in their respective networks and their educational performance (Castillo et al., 2021). This study further established that the social characteristics of individuals within their networks significantly impacted educational outcomes. These findings highlight the potential of SNA to identify key interaction patterns that influence learning outcomes. Therefore, this study aims to apply SNA in a face-to-face medical PBL setting to explore how peer-assessed collaborative work relates to academic achievement and group dynamics.

In the context of medical education, SNA has been steadily increasingly applied. It is often used to study collaboration among medical students and healthcare professionals. Isba et al. (2017) highlights the relevance of SNA, which would yield significant insights that would improve experiences and outcomes for medical trainees and educators. However, despite its relevance, it has also been highlighted that SNA has been underused in the context of medical education (Isba et al., 2017). Nonetheless, Saqr et al. (2019) conducted a study on online problem-based learning among dental students and found that using multiple regression analysis, SNA centrality measures could be used to predict group performances (Saqr et al., 2019). Another study by Saqr et al. (2020) visualised the social networks of PBL and precisely mapped each PBL group and the activity level within the group. They were able to identify both isolated

and active students and found that students' level of activity and interaction with tutors are positively correlated with academic performance (Saqr et al., 2020).

Building on these insights, this study aims to investigate SNA networks among PBL groups in medical education in a non-virtual setting. SNA has been a learning analytic tool that has been proven helpful in multiple contexts but is lacking in medical education. SNA methods, such as measures of centrality and subgroup analysis, can be used to observe the correlation between student participation and exam performance while identifying possible underperforming students. Thus, early identification and intervention among the participating students can be achieved.

CHAPTER III

METHODOLOGY

3.1   STUDY DESIGN

This short-term pilot study uses a cross-sectional and comparative network analysis approach.

3.2   SAMPLING

This study will use cluster sampling. The study population is 208 Yeaar1 medical students and 184 Year 2 medical students of Universiti Kebangsaan Malaysia participating in PBL sessions. The total number of PBL groups among Year 1 and Year 2 medical students is 40. Taking into account the intracluster correlation, Killip et al. (2004) recommends rho value of 0.01-0.02 (Killip et al., 2004). Therefore, the calculated effective sample size (ESS) as in equation 1.1 is 80 students. This rounds the number of

$$ESS = \frac{mk}{1+\rho(m-1)} = \frac{392\cdot1}{1+0.01\cdot(392-1)} = \frac{392}{4.91} \approx 80 \; students \qquad \text{…(1.1)}$$

$$80 \text{ students} = \frac{80}{10} \approx 8 \text{ PBL Groups} \qquad \text{…(1.2)}$$

3.3 STUDY INSTRUMENT

The questionnaire that will be used is from Elizondo-Montemayor (2004) and was further adopted for Problem-Based Learning and validated by Alias et al. (2015) (Alias et al., 2015; Elizondo-Montemayor, 2004). The validated questionnaire by Alias et al is provided in Table 1, where students indicate the level of their agreement to the given statements on a scale of 1 to 4, indicating a strong disagreement to strong agreement respectively. The reliability testing conducted by Alias et al. using the Cronbach Alpha method is r=.97 (Alias et al., 2015).

	1	2	3	4
Consistently gives priority to group discussion (*Sentiasa mengutamakan perbincangan secara berkumpulan*)				
Participates actively in group activities (*Bergiat aktif dalam aktiviti yang dijalankan dalam kumpulan)*				
Contribute many ideas to group discussion (*Menyumbang banyak ide dalam perbincangan secara berkumpulan*)				
Carry out work delegated diligently (*Melaksanakan tugas yang diberikan dalam kumpulan dengan sempurna*)				
Share new information with peers during discussion (*Sentiasa berkongsi maklumat baru dengan rakan-rakan dalam perbincangan kumpulan*)				

Table 1 Peer Assessment Items

3.4 STUDY PROTOCOL

Interaction data will be collected, where each student will fill out the peer interaction form and rank their top 3 most interactive peers. Data and consent will be taken using Google Forms shared via WhatsApp. Peer assessment is conducted using a structured rubric consisting of five 4-point Likert-scale items as above, yielding a total possible

score of 5 to 20 per peer-reviewed student. This score reflects perceived quality of collaboration, including participation, respectfulness, and teamwork. While peer assessments provide rich insights into the quality of interactions, it does not fully capture interaction frequency or social prominence. To address this, students also nominate their top three most frequently or meaningfully interacted peers. These rankings are converted to weighted points (Top 1 = 3 points, Top 2 = 2 points, Top 3 = 1 point), aggregated across the group, and normalized. The rankings will be converted into a weighted adjacency matrix for network analysis, as;

$$w_{A \to B} = 0.7 \cdot NormalizedCollab_{A \to B} + 0.3 \cdot NormalizedRank_{A \to B} \qquad …(1.3)$$

Referring to equation 1.3, where the directional weight from student A to B will be weighted 70% onto normalized collaborative score (*NormalizedCollab)*, and 30% onto rank of peer interaction (*NormalizedRank*), forming a hybrid score of balanced measures of both perceived collaboration quality and observed interaction prominence. Individual exam scores will be collected and compared to students' network positions at the end of the study module. Once data has been collected, the network will be processed to measure centrality (degree, closeness, betweenness) and modularity. Centrality scores will be correlated with exam performance, and subgroups will be analysed to identify learning patterns.

3.5 ANALYSIS

The collected data will be analysed using R software. The analysis framework will be as in Table 2.

Research Objective	Statistical Methods
To compare the structural differences and interaction dynamics across multiple PBL discussion networks.	Descriptive Network Metrics
To examine the relationship between individual centrality measures (e.g., degree, betweenness, closeness) within	Correlation Analysis

PBL networks and students' exam performance.	
To identify distinctive network patterns and interaction characteristics associated with underperforming students in PBL discussions.	Subgroup Analysis

Table 2 Summary of Statistical Methods

3.6 INCLUSION CRITERIA

Year 1 and Year 2 (Preclinical) medical students, Faculty of Medicine, Universiti Kebangsaan Malaysia.

3.7 EXCLUSION CRITERIA

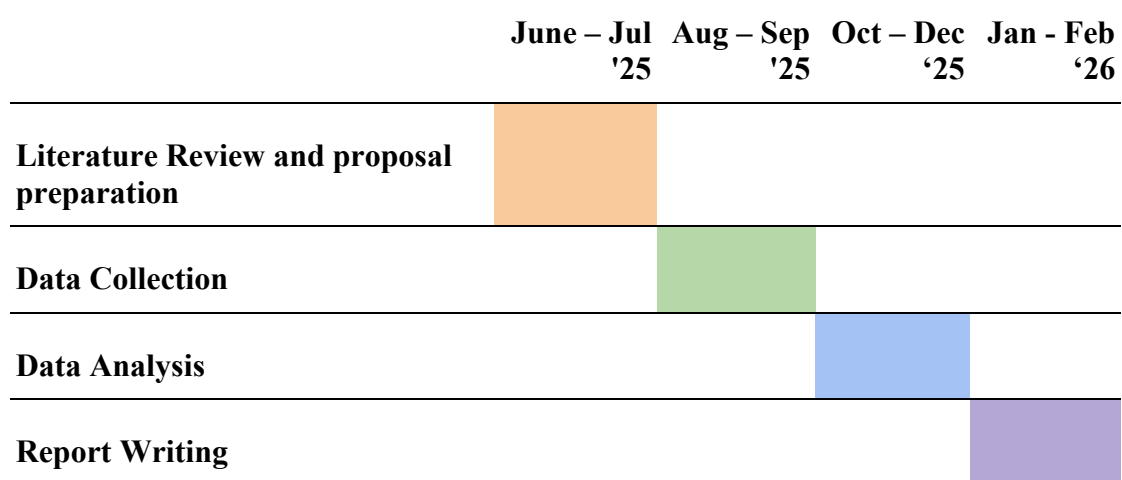Groups with incomplete data, and absentee students >50% of PBL sessions.

3.8 DURATION OF STUDY

July 2025 – Feb 2026

CHAPTER IV

GANTT CHART

	June – Jul '25	Aug – Sep '25	Oct – Dec '25	Jan - Feb '26
Literature Review and proposal preparation	■			
Data Collection		■		
Data Analysis			■	
Report Writing				■

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