Epistemic Network Models of Students' Cognitive Engagement and Teachers' Feedback in Online Research Writing Courses

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Abstract
Understanding cultural systems in online learning with voluminous data, such as the engagement of students and teachers, has proven to be challenging. This predicament catalyzed the need for an emerging methodology to assess learning and complex thinking in online environments using statistical tools to analyze qualitative data. Quantitative Ethnography (QE) blends qualitative and quantitative approaches and uses statistical tools in analyzing qualitative data. This study advanced Epistemic Network Analysis (ENA), a QE tool, to analyze the engagement of teachers and students in online research courses of six groups of students. Observation of synchronous classes and asynchronous activities was carried out, 4,137 utterances were coded, and network models of engagements were generated. The findings show that the ENA engagement models among teachers and students in synchronous and asynchronous sessions differed significantly, with the teachers giving more frequent and varied feedback during synchronous classes. The network models of engagement in synchronous classes reveal the co-occurrence of students' cognitive engagement and teachers' feedback. When students try to connect with the lesson, they are given corrective feedback, and when they extend their understanding of the content, they are given affective feedback. On the other hand, when students are given prompts during asynchronous sessions, they try to connect. When they simply agree, they are given informative-procedural feedback, and when they emancipate their understanding, they receive affective feedback. This study illuminates the methodological advantages of ENA as an ethnographic tool that mixes qualitative and quantitative approaches in understanding cultural systems and processes in online education.

Keywords: Epistemic network analysis, cognitive engagement, teacher feedback, online research writing course

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While the COVID-19 pandemic has had a catastrophic impact on the world, such as interrupted learning and learning loss in education, it has paved the way to breakthrough realizations, innovations, and opportunities. The forced closure of schools and the health emergency crisis have caused a shift and transformation in educational models and pedagogies, realizing that learners can also learn anywhere and anytime through online learning. The future of education after the pandemic is poised to continue online learning and using digital technologies because of its benefits, such as accessibility, flexibility, efficiency, and practicality (Bright & Vogler, 2024; Ravichandran & Kohli, 2022). Online learning will continue to flourish in the education sector. Even before the pandemic caused an unimaginable change, online learning is believed to be the next education leap forward (Meier, 2015). At present, while there are some schools and universities who reverted to traditional face-to-face learning, there are still some education institutions that are offering various courses using completely online, hybrid, and hyflex modalities.

Dhawan (2020) describes online learning as the learning experiences in synchronous or asynchronous environments using devices such as computers and mobile phones with internet access. The continuity of online learning modality calls for the need to persistently investigate factors and areas that affect its effectiveness. Two of the many challenges point to the low engagement of students (Mamun et al., 2016; Hu & Li, 2017; Hollister et al., 2022; Kristiana et al., 2023; Means & Neisler, 2023) and limited teachers' feedback practices (Hysaj & Haroon, 2022; Hilbert et al., 2023; Hodge & Chenelle, 2018). Some online learners are challenged to maintain their motivation, communication, and maintain student-teacher, student-student, and student-content engagement (Gilbert, 2015) and teachers mentioned that workload time constraints affect their feedback practices in online learning (Harnin et al., 2022). Contemporary online learning includes interactions between teachers and students to help them gain knowledge and grow personally and professionally in virtual classroom settings (Altowairiki, 2023).

Farrell and Brunton (2020) defined student engagement as students' emotional, behavioral, and cognitive connection to their studies, which has been shown to influence their learning achievement. Cognitive engagement (CE) is one of several dimensions of student engagement. It is defined as students' personal investment in learning activities, which includes a commitment to mastery learning, using study strategies, and self-regulation (Pietarinen et al., 2014). In online learning environments, it is operationalized as the combination of students' knowledge, thinking process, effort, and commitment to connect with the lesson and the class. Students can manifest this engagement by participating actively in the class, employing critical thinking and problem-solving skills, and utilizing teacher feedback during online classes.

The impact of teachers on the learning engagement of students is profound as they assume a pivotal role in fostering student engagement (Pedler et al., 2020) and designing a caring and stimulating educational environment (Conklin et al., 2024; Shernoff et al., 2016). Teachers are expected to create a strong sense of community so that students will always feel connected with their peers, instructors, and the content (Everett, 2015), particularly in online learning, where students need to be vigorously and dynamically involved compared to traditional classrooms. In online learning, teachers communicate, connect, and engage with students by providing feedback. Teacher feedback is believed to be the driving force that creates awareness among students about their performance. Shute (2008) defines feedback as communication information given to students to correct their behaviors to improve their learning. Feedback can facilitate students' reflection on their achievements, strengths, and weaknesses and how they may correct and improve their performance. An effective feedback system can increase students' self-efficacy, positively impacting their learning engagement and achievement.

Teachers' feedback and students' cognitive engagement are two dynamic constructs in teaching and learning that researchers have studied extensively worldwide. Most studies, however, focus on face-to-face learning environments, and only a few have paid attention to online learning. This is explicable since online learning had been regarded as an alternative learning modality until the global health crisis changed the landscape of education. Investigating the connection between teacher feedback and students' cognitive engagement is pertinent during exploration and abrupt change. Providing online feedback to students differs from traditional feedback provided in classroom settings; non-verbal communication is absent in written online feedback (Leibold & Schwarz, 2015). Teachers' extent of control over students' engagement is quite slack because they do not share physical proximity (DeWitt, 2020).

Given the complexity and demands of studying the relationship between students' cognitive engagement and teacher feedback, the researcher utilized Epistemic Network Analysis (ENA), a novel quantitative ethnography tool that can quantify, visualize, and interpret network data. It uses techniques that identify and measure connections among elements in coded data and represents them in dynamic network models (Shaffer et al., 2017). This study employed ENA to construct models that associate patterns in any system, such as the interaction of teacher feedback and cognitive engagement in the context of online research courses.

> This study aims to expand the existing but limited body of knowledge about the connection between teacher feedback and cognitive engagement among students in online research courses. This study aims to contribute to the emerging field of Quantitative Ethnography by using an innovative tool called Epistemic Network Analysis to develop models that can quantitatively summarize the engagement of teachers and students in an online learning environment. The primary question that was answered in this inquiry was: What epistemic network models represent the co-occurrence of teachers' feedback and cognitive engagement of students in online synchronous and asynchronous research courses?

Review of Literature

Teacher Feedback and Cognitive Engagement of Students

Feedback is imperative to the teaching and learning process as it can cultivate positive learning gains and experiences when used effectively and appropriately by teachers and students. It is a piece of communicative information given to students to correct their performance and behavior to improve their learning (Shute, as cited in Ocak & Karafil, 2020). Teacher feedback (TF) is multi-dimensional, serving varying purposes (Anthony et al., 2019), connected to the formal function of assessment (Eriksson et al., 2018), and can promote student-teacher relationships, student academic involvement, and self-regulation (Fonseca et al., 2015).

Along with teacher feedback, this study focused on cognitive engagement, described as students' investment in learning activities (Pilotti et al., 2017). In addition, it is a term used to describe students' beliefs about the importance of schooling, learning goals, and future aspirations. It can be seen through learners' strategies to deeply understand the material and manage learning processes such as planning and seeking information that require self-regulatory and metacognitive techniques. It may be manifested when students do extra work and perform beyond expectation. Thus, CE involves motivation, self-regulated learning, and learning strategies (Fredricks & McColskey, 2012).

Teachers' involvement in online learning frequently entails providing feedback that appeals to the students' affective domains, demonstrating empathy and an interest in understanding them. Arapakis et al. (2008) demonstrate how affective feedback in the classroom can encourage students to engage in processes such as connecting with teachers. When combined with cognitive feedback, affective feedback positively impacts student engagement. According to Lu and Law (2012), task engagement increases when teachers provide guidance on how to participate more effectively. However, anecdotes indicate that teachers provide more feedback during live online sessions than offline ones. Zhohar and Smith, as cited in Leibold and Schwarz (2015), found that students frequently complain about insufficient positive feedback in online courses. According to Pappas (2015), delayed feedback is a common challenge in asynchronous learning, and feedback should be returned within a week to help students address areas for improvement as soon as possible (Leibold and Schwarz, 2015). Furthermore, Borup (2021) discovered that text-based feedback is time-consuming, frequently resulting in delays and generic responses. Despite these issues, the effectiveness of electronic feedback is still under investigation (Ene & Upton, 2018).

In contrast, studies show that students engage more effectively during offline sessions in distance education. Garrison and Innes, as cited in Malik et al. (2017), discovered that students in asynchronous sessions actively sought out the content provided by teachers and engaged in meaningful learning tasks. According to Pappas (2015), asynchronous modalities benefit introverted students who are uncomfortable participating in live discussions by allowing them to share insights without fear of judgment. Engaging students in online learning presents unique challenges for educators, who must constantly seek ways to foster connection and keep students from feeling isolated (Sebastien, 2021).

Epistemic Network Analysis (ENA): A Quantitative Ethnography Tool

ENA is a set of techniques that identify and measure connections among coded data elements and represent them in dynamic network models (Shaffer et al., 2017). According to the proponents of the quantitative ethnographic tool from the Wisconsin Center for Education Research of the University of Wisconsin-Madison, ENA is a versatile method that can address quantitative and qualitative research questions concerning patterns of association of data hypothesized to be meaningful. This study hypothesizes teacher feedback and students' cognitive engagement to have a meaningful association.

To understand how ENA can help the researcher realize the objectives of this study, it is vital to understand the theoretical assumptions and bases of this methodology. ENA was initially developed to create cognitive networks, consisting of the association among knowledge, skills, values, habits of mind, and other elements that illustrate the complex cognitive process (Shaffer et al., 2016). ENA is a conceivable analytical tool because it considers the connection among coded elements rather than their mere presence or absence in isolation. Most studies about teacher feedback and students' cognitive engagement in the past have treated these variables in isolation, like investigating the extent to which teacher feedback is practiced in classes and exploring the levels of students' cognitive engagement in a particular discipline.

ENA was utilized to measure thinking and skills among participants in epistemic games. Hatfield (2015) developed an epistemic frame in a journalism game where students assumed journalists' roles and interacted with students and mentors in this practicum activity. Teachers' Technological Pedagogical Content Knowledge (TPACK) was examined using ENA by comparing the salient elements of the knowledge network generated by different groups of teachers (Zhang et al., 2019). Another insightful application of ENA was found in the study of Fougt et al. (2018), who investigated students' written formative and summative assignments in Denmark. ENA was used to develop pedagogical visualizations of discursive networks in the written assignment of students. The findings show that ENA could differentiate students' cognitive connections when grouped according to their performance. High-performing students demonstrate better relationships than middle-performing students with a higher mean network. Similarly, middle-performing students formed better connections than low-performing students.

Methods

Research Design

Quantitative ethnography is the main research design of this inquiry. This research design was used in modelling the relationship and interaction of teacher feedback and students' cognitive engagement in online learning because it is eminently suited to describing and exploring phenomena in digital, virtual, online, and networked environments. Ethnography is a flexible and responsive methodology sensitive to emergent phenomena and research questions (Howard & Mawyer, 2015). Observation of synchronous and asynchronous classes and interviews of selected participants were conducted almost in the same phase.

ENA is a quantitative ethnography tool that uses statistics to analyze networks of cognitive interaction. While data collection started by coding textual and verbal data—considered qualitative—the primary method used was technically quantitative. It refers to the numerical translation, transformation, and conversion of qualitative data (Sandelowski et al., 2019). In quantitizing the ethnographic data in this research, interviews and observations were coded for analysis. Thus, the network models of online learning engagement in this study were a product of mixed data, which affirmed the nature of quantitative ethnography.

Research Locale and Setting

The research locale of this study is one private senior high school in Quezon City, Philippines. While obtaining data from more than one locality may contribute to one study's generalizability or external validity, ENA is a robust tool that works well even with a small sample size from one setting. The sample determination of this study is research-based. A number of studies from the past years conducted ENA studies involving a small group from one setting (Andrist et al., 2019; Bressler et al., 2019; Cai et al., 2017). The research setting was online because the research courses are facilitated using online learning platforms. Live or recorded online discussions in Google Meet or Zoom were observed for synchronous learning activities. The learning management system used by the teachers and students was the data collection setting for asynchronous learning activities.

Participants and Sampling

The researcher chose the senior high school because it is assumed that the interaction of teacher feedback and students' cognitive engagement was more evident compared to the lower levels. Also, three strands were included in this study, namely Science, Technology, Engineering and Mathematics (STEM), Accountancy, Business, and Management (ABM), and Humanities and Social Sciences (HUMSS). The total number of students involved in the observation of online classes is 266, while the total number of teachers requested to participate is three. Also, five students and three teachers were interviewed. The tables below summarize the demographic profile of the participants.

Table 1

Student- Respondents for the ENA Modeling

Strand and Section	Number of Students in Class	Total Strand Population	Percentage
ABM Group 1	47	92	34.58%
ABM Group 2	45		
HUMSS Group 1	46	87	32.71%
HUMSS Group 1	41		
STEM Group 1	42	87	32.71%
STEM Group 2	45		
Total:		266	100%

The six groups of students were enrolled in online research courses under the same teacher. This allows the comparison of the network models using Epistemic Network Analysis. Purposive sampling was the researcher's sampling technique for the qualitative data-gathering phase for every research question. According to Patton (2002, as cited in Palinkas et al., 2015), purposeful sampling is widely used in qualitative research to identify and select information-rich cases for the most effective use of limited resources. In this phase, the researcher considered homogeneity purposive sampling to describe a particular subgroup in-depth, reduce variation, simplify the analysis, and facilitate group interviewing. This is useful to augment the information provided by the statistical network model of teacher feedback and students' cognitive engagement in online learning. Moreover, network modelling using ENA is good enough when a model's number of units (number of respondents) exceeds the number of nodes (codes). Since there are 11 nodes in this study, a network model of online learning engagement can be constructed when there are at least eleven units (respondents).

Data Gathering Procedure

The researchers sought the approval of the concerned school administrators of the intended locality to conduct the study. The letter of request was sent to the concerned school official, where the primary purpose of the study, demands of data gathering procedures, and the ethical issues and considerations related to the conduct of this research were articulated.

Also, informed consent among participants was solicited by the researcher at the onset of the data collection procedure. In this process, participants were informed about the study's objectives and their expected participation. In this agreement, it was discussed that only the researcher was allowed to observe online classes and access the accounts of the participating teachers in the school's Learning Management System. The faces of the participants and any form of their identification were held private and strictly confidential by the researcher. After approval and informed consent were obtained, the researcher commenced gathering data. The actual procedure consisted of two phases.

The data gathering procedure took place during the Academic Year 2022-2023, from March to June 2023. Data collection occurred in intervals based on the class schedule and the availability of the discourses to be observed and analyzed. In the first phase, the researcher focused on analyzing teachers' and students' discourses during synchronous classes to explore how teacher feedback and students' cognitive engagement co-occur in online discussions. A total of 36 classes were observed: 21 classes were observed live, while the remaining classes were reviewed through videotaped sessions provided by the teacher-participants. Classes were observed from Monday to Thursday, and teachers and students were interviewed on Fridays.

The second phase focused on analyzing the discourses of teachers and students during asynchronous activities, which were observed and collected simultaneously by the researcher. The researcher accessed the discourses through the Learning Management System (LMS) used by the concerned school. A total of 36 sessions or activities were observed and coded. Although the researcher observed 72 sessions in total, only the parts of the lessons where meaningful engagement between teachers and students was observed were transcribed and coded. Not all sessions contained significant engagement among the participants. Some participants with meaningful engagements during asynchronous sessions were interviewed according to their preferred schedule.

Data Analysis

This study used Epistemic Network Analysis to analyze ethnographic data in online research classes. Using visual graphs and statistics, ENA was used to describe and understand the structure of engagement among teachers and students. Before running ENA, a crucial step is to prepare the qualitative data and carefully transform and quantitize raw utterances. A coding scheme was observed in preparing the dataset.

<u>Discourse Analysis and Coding Scheme</u>

Discourse analysis focuses on how language is used between people in written and spoken contexts. It looks at a running conversation involving a speaker and listener. In this particular study, discourse analysis focusing on the interaction of teacher feedback and students' cognitive engagement was investigated in both synchronous and asynchronous learning activities.

Since ENA was used to model the structure of the relationship between the two variables, one preliminary process is transcribing and coding unit of discourse based on the empirically based types of Teacher Feedback (TF) by Savvidou (2018) and Cognitive Engagement (CE) levels by Casimiro (2016). In qualitative research, transcription provides researchers with texts that are precise; these enable researchers to read, analyze, and interpret data. (Tiwari et al., 2018). Coding is labelling and organizing qualitative data to identify themes and their relationships (Medelyan, 2020).

The researcher transcribed spoken and written data from both synchronous and asynchronous learning events. Each unit of discourse was coded using predetermined categories of teacher feedback and students' cognitive engagement, which were applied in the ENA modelling. Since modelling may be influenced by bias, selectivity, and personal judgment, the coders relied on clear indicators and descriptors to guide the coding process and ensure consistency. The following tables summarize the coding schemes for both teacher feedback (TF) and cognitive engagement (CE) based on the literature review.

Table 2

Teacher Feedback Discourse Codes and Descriptions (Savvidou, 2017)

Discourse Codes	Descriptions	Sample Utterances
Affective	a. Salutations, Phatic Expressions	*It is nice to see all of you again virtually. I am excited to discover what is in store for us in 2021.*
	b. Vocatives	*Thank you for your submission, Tracy.*
	c. Complimenting and expressing appreciation	*Your manuscript exceeded my expectations. All your hard work paid off!*
	d. Empathetic	*I understand you faced a personal problem last week, but you must submit your project tomorrow.*
	e. Supportive	*Just let me know if you have further questions.*

	f. Self-disclosure	*When I was doing my thesis five years ago, I had a terrible experience.*
2. Corrective	Positive or negative evaluation of Students' response	*Your explanation is substantial and logical.*
3.Informative Content	Comments on the content of the course	*Reliability has something to do with measurement errors.*
4. Informative Procedural	Directs students to do a specific procedure related to the task	*You should revise your study's conceptual framework and explain how your study's variables are associated with each other.*
5. Reflective	Encourages reflection among students on how their understanding of the lesson is related to their personal experiences and exercise metacognitive thinking	*How can you possibly strengthen the rigor of your research methodology?*

In Table 2, teacher feedback codes and descriptions are presented. Savvidou (2017) developed a hierarchy of codes on how teachers engage with students. Affective feedback involves salutations, phatic expressions, vocatives, compliments, and empathetic, supportive, and self-disclosure examples. This feedback is what teachers give in different aspects of the class that have varied purposes, such as showing students support. Corrective feedback is also widespread when teachers evaluate the correctness of students' responses. Also, teachers usually provide students not only with affective and corrective feedback but with informative feedback, such as informative content and informative procedures. Lastly, teachers provide reflective feedback that encourages reflection among students and how their understanding of the lesson is related to their personal experiences. Table 3 below summarizes the levels of cognitive engagement among students.

Table 3

Levels of Cognitive Engagement, Codes, and Descriptions (Casimiro, 2016)

Discourse Codes	Descriptions	Sample Utterances
1. Non- Response	Zero or Minimal Engagement	*No response or unrelated response*
2. Simply Agreeing	a. Mere agreement and acknowledgment with the teacher's feedback	*This is noted, and I will follow your advice.*

	b. Desire to connect with the teacher or with others for their presence to be felt in class	*We already submitted our work.*
3. Connecting	Attempt to respond but based on the answer purely on personal opinion or experience and may lack scholarship.	*I included this part because I thought this would work since my classmate used the same argument.*
4. Extending	Responds to questions based on scholarly evidence and show interest by asking further questions or clarifications along the same line of argument	*I included this part because this will explain the reason for such a relationship. Do I need to improve this further?*
5. Expanding	Responds to questions but add new ideas to the discussion, apply new concepts to a new situation, or consider relevant implications	*I included this part because this will explain the reason for such a relationship. Moreover, I also did triangulation to verify the initial results. I will apply the same to the succeeding questions for consistency and clarity.*
6. Emancipating	Evidence of mastery of the content and skills by applying critical thinking and making personal convictions; opens to intellectual conflict without fear of being judged	*I included this part because this will explain the reason for such a relationship. Moreover, I also did triangulation to verify the initial results. I was able to compare what I did to the works of others, and I can say that this strengthens the findings of my study. I would love to hear what I can do further to improve my work.*

In Table 3, cognitive engagement codes among students were explained. Casimiro (2016) categorized nonresponse as minimal engagement from students. Simply agreeing manifests an engagement as a desire to connect but is weak. Connecting is a kind of engagement where students attempt to respond but base the answer purely on personal opinion or experience and may lack scholarship. The following three levels of engagement are believed to be superior to the first three. Extending happens when students respond to questions with scholarly evidence and a desire to learn more by asking further questions. Expanding takes place when students add more information, and emancipating shows students' evidence of mastery of the content and skills by making personal convictions without any signs of intellectual apprehension.

Since the codes are pre-defined concepts derived from existing theoretical and empirical studies, the coders employed a priori coding. According to Cai et al. (2019), a priori coding—also referred to as theoretical, deductive, or top-down coding—begins with a theory or set of constructs, and then searches for corresponding ideas within the data, rather than starting with the ideas found in the data itself. The tables presented serve as the codebooks used in the coding process. Three coders, including the researcher and two other practitioners, carried out the rigorous and critical task of coding. They held numerous virtual meetings to ensure a shared understanding of the codes. This step was essential, as the coders were expected to generate valid insights and apply the codes consistently. Additionally, Krippendorff's alpha (also known as k-alpha) was calculated to verify that each relevant utterance in the discourse was coded accurately and consistently. The reliability coefficients ranged from 0.8028 to 0.9492.

Epistemic Network Analysis

ENA is an analytic tool with its own language and set of procedures exclusive to itself. Thus, understanding how ENA was used in modelling the co-occurrence of teacher feedback and students' cognitive engagement in online learning is helpful in understanding the mathematics behind ENA.

In the case of teacher-student interaction, the epistemic frame of teacher feedback (TF) is characterized by f_i, where $i =$ appreciative, corrective, informative-content, informative-procedure, and reflective, and characterized cognitive engagement (CE) of students where $j =$ non-response, simply agreeing, connecting, extending, expanding, and emancipating. For every time t, where $t = 1,2,3, \dots n,$ and any teacher or student $a,$ there will be ${D^a}_t$ that is a snapshot or segment of the interaction of the kind TF and CE made by teachers and students. Thus, the connection of the epistemic frame elements of f_i and f_j for teacher and student a at time t is given by the adjacency matrix below: **M**= $\boldsymbol{1\ if\ both\ f_i}$ and $\boldsymbol{f_j}$ are both in $\boldsymbol{{D^a}_t}$

Since online learning exposure in this study is viewed as synchronous and asynchronous, each online activity's epistemic network can be generated by summing each pair of frame elements. Thus, for the epistemic network of teacher feedback and students' cognitive engagement in synchronous activity, where $t = 1, n,$ we will have the cumulative adjacency matrix F^a:

$$\boldsymbol{F^{a,t\,[1,n]} = \sum_1^n M^{a,n}}$$

Moreover, other statistical measures need to be calculated to understand better the epistemic frames of teacher feedback models and students' cognitive engagement, such as the centrality or connectedness of the individual elements f_i and f_j. The relevance of centrality in ENA is that it describes how tightly bounded an epistemic frame element is to the other frame elements (Svarovsky, 2011). In this study, the weight of the connectedness of teacher feedback and cognitive engagement of students in the epistemic network, F is given by the sum of the square's centrality:

$$C(Fi) = \sqrt{\sum_j (F_{i,j})^2}$$

From this result, the relative centrality, R of a particular epistemic frame is calculated using the formula:

$$R(f_i) = \frac{C(f_i)}{C_{max}(F)} \; x \; 100$$

Modelling Network Data Using ENA

ENA produces an adjacency matrix in modelling network data for every stanza-based interaction. The adjacency matrix is simply a way of summarizing the strengths of the relations between objects. For this study, the researcher is concerned about the co-occurrence of teacher feedback and cognitive engagement of students for teacher-student interaction and the co-occurrence of cognitive engagement among students. A code of 1 is written if both codes occur in one stanza, while zero if both codes do not appear in the same stanza. Moreover, the diagonal is blocked because a particular code cannot establish a co-occurrence of relationship to itself. Every unit in a stanza has one adjacency matrix. Below is an example of the said matrix. Table 4 further explains the adjacency matrix relevant to ENA modelling of engagement among teachers and students in online learning.

Table 4

Adjacency Matrix in ENA Modeling of Interaction of Teacher Feedback and Students' Cognitive Engagement Codes

Codes	Affective	Corrective	Informative-Content	Informative-Procedural	Reflective	No-Response	Simply Agreeing	Connecting	Extending	Expanding	Emancipating
Affective		0	0	0	0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
Corrective	0		0	0	0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
Informative-Content	0	0		0	0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
Informative-Procedural	0	0	0		0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
Reflective	0	0	0	0		0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
No-Response	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1		0 or 1	0 or 1	0 or 1	0 or 1	0 or 1
Simply Agreeing	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1		0 or 1	0 or 1	0 or 1	0 or 1
Connecting	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1		0 or 1	0 or 1	0 or 1
Extending	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1		0 or 1	0 or 1
Expanding	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1		0 or 1
Emancipating	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	

Table 4 displays the adjacency matrix in ENA modelling the interaction between the teacher feedback and students' cognitive engagement codes. To construct a network model from data in ENA format, ENA converts the code columns into an adjacency matrix for each stanza in the data and adds the adjacency matrices together into a *cumulative adjacency matrix* for the network.

The researcher initially consulted with the Epistemic Network Laboratory of the University of Wisconsin-Madison and sought their assistance on how to format data correctly, as the ENA web tool requires datasets to have a specific shape. The Excel template was prepared, and the units, conversations, stanzas, and codes were identified.
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The unit of analysis is the participants, who are the teachers and senior high school students. Conversations are collections of lines within which ENA models connections between concepts. There were different conversations where the ENA models were constructed, namely the type of instructional distance delivery, courses, and strands of students. In modelling teacher feedback and students' cognitive engagement, the *moving stanza* method was used, which means that ENA modelled connections within the conversation by dividing it into multiple stanza windows. In this study, the researcher used two-moving stanzas for student-teacher engagement and four-moves for student-student engagement. In this particular method it only models connections between lines that are in close temporal proximity within a conversation. Moreover, the researcher used the entire conversation to model the interaction of cognitive engagement among students, provided that this engagement is facilitated by teacher feedback within a conversation.

ENA constructs dynamic network models among coded data and can be interpreted visually and through summary statistics. The network models showed the structure of connection among different nodes (codes) using the lines that connect them. Also, ENA models measure weighted density that can easily be depicted by looking at each line's thickness. The structure or pattern of connecting among nodes is an added value to ENA, which other network methodologies cannot describe. In the analytic space, network models can be compared, such as those conversations between two different strands and the types of online learning tasks.

Also, the centroid of each network can be used to compare different networks simultaneously. Centroids of networks close to each other may have similar patterns of connections among codes. ENA assigned a fixed position for each node, and the position of these nodes was used to interpret the projection space created by the X- and Y- axes. This is where the researcher made meaningful interpretations about each dimension.

Results

Epistemic Network Models of Teachers' Feedback and Students' Cognitive Engagement in Online Synchronous and Asynchronous Research Writing Tasks

Before presenting the generated ENA models of online learning engagement of teachers and students, the succeeding tables describe the total number of utterances and their codes observed, transcribed, and categorized by the researcher across three courses. Table 1 describes the total number of observed utterances in asynchronous tasks.

Table 5

Number of Utterances in Synchronous and Asynchronous Tasks

Course	Type of Online Learning Task		Total
	Synchronous	Asynchronous	
Qualitative Research	764 18.47%	624 15.08%	1388 33.55%
Quantitative Research	679 16.41%	643 15.54%	1322 31.95%
Culminating Research Project	736 17.79%	691 16.71%	1427 34.50%
Total:	2,179 52.67%	1,958 47.33%	4,137 100.00%

Table 5 shows 4,137 lines of utterances transcribed and coded from 72 sessions (3 classes x 4 sessions x 6 learning tasks). It can be gleaned from the data that 1,427 lines or 34.50% were observed in the Culminating Research Project course, 1,388 or 33.55% in the Quantitative Research course, and 1,322 or 31.95%, in the Qualitative Research course. In addition, 2,179 codes, or 52.67% were obtained from synchronous classes, while 1,958 codes or 47.33% were taken from asynchronous activities. Table 2 outlines the number of utterances among the participants.

Figure 1

Epistemic Network of Engagement in Synchronous and Asynchronous Research Writing Courses

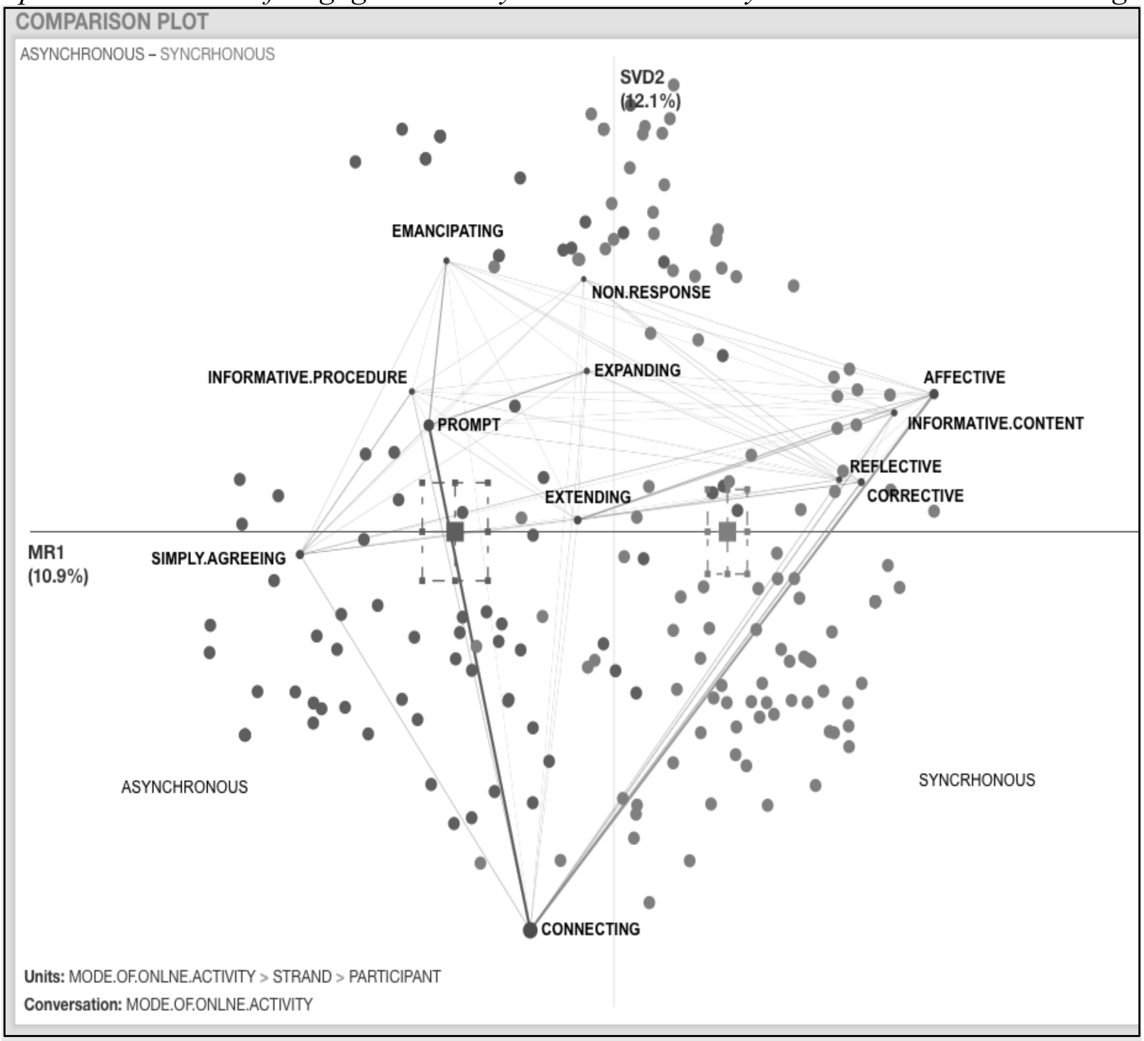

Figure 1 shows the ENA model of engagement of teachers and students in asynchronous and synchronous activities. The presented network model shows the projection space capturing the structure of engagement of teachers and students in both synchronous (lines on the right side of the y-axis) and asynchronous (lines on the left side of the y-axis) activities. The unconnected dots are units of the network: the students and teachers. The dots linked by the lines are called the *nodes*: the teacher feedback codes and students' cognitive engagement codes. These nodes have fixed positions in the projection space for all the datasets to allow meaningful group comparisons. The lines connecting two nodes describe their relationship; thicker lines mean stronger relationships. The squares are the centroids of each conversation, which is the center of the network diagram. Mathematically, the centroid's position depends on the network units' weighted connections.

The ENA model explains 10.9% variance along the x-axis and 12.1% variance along the y-axis of the structure of engagement between teachers and students. The goodness of fit of the network model also has a co-registration of $r = 0.79$ on the x-axis and $r = 0.78$ on the y-axis, which means that the model has a good fit. In addition, it is very apparent that the structures of connections between teachers and students in synchronous and asynchronous learning activities are different, with the network centroid of asynchronous classes positioned on the left side and the centroid of the synchronous classes fixed on the right side. The results of the t-test along the x-axis (MR1) confirm that the structure of connections of teacher-student engagement significantly differs between the two modes of online activities $[t(126.37) = 14.14; \mathrm{p-value} = 0.00)]$, with effect size, $d = 2.26$, which indicates a very large effect. However, no significant difference was detected along the y-axis (SV2) where$[t(161.84)14.14; \mathrm{p-value} = 1.00)]$.

Analyzing the projection space, ENA positioned most of the codes of engagement in synchronous sessions on the right side. Most teacher feedback nodes (affective, corrective, informative-content, and reflective) are situated in Quadrant 1 of the plane. This implies that teachers provided more feedback in synchronous sessions than in asynchronous sessions. Also, higher cognitive engagement nodes among students are positioned in Quadrant 2, meaning that students in synchronous sessions displayed higher cognitive engagement (extending, expanding, and emancipating) during live online sessions. On the other hand, ENA positioned the engagement of teachers and students on the left side of the projection space. It can be seen there that the most prominent engagement is prompt-connecting and prompt-emancipating. Teacher feedback is less evident in asynchronous sessions.

Epistemic Network Analysis also presents visual and statistical information to detect differences in the relationships of two codes. The succeeding table verifies the visual information presented in the generated ENA model.

Table 6

Weighted Connections Between Students' Cognitive Engagement and Teachers' Feedback in Online Learning

Pair of Nodes	Synchronous	Asynchronous	Difference	*Where is the connection stronger?*
Connecting-Corrective	0.21	0.10	0.11	Synchronous
Connecting-Informative Content	0.14	0.08	0.06	Synchronous
Extending-Affective	0.15	0.06	0.09	Synchronous
Extending-Informative Content	0.12	0.04	0.08	Synchronous
Prompt-Connecting	0.20	0.41	-0.21	Asynchronous

Simply Agreeing-Affective	0.14	0.19	-0.05	Asynchronous
Prompt-Emancipating	0.01	0.11	-0.10	Asynchronous
Simply Agreeing-Informative Procedural	0.03	0.10	-0.07	Asynchronous

The table above confirms the visual representation of the co-occurrence of students' cognitive engagement and teachers' feedback in online learning. Among the prominent interactions between the two codes are students' connecting and teachers' corrective feedback (0.11) for synchronous sessions and teachers' prompt and students' connecting (0.21) in asynchronous sessions.

The ENA visual model and summary statistics provide useful information in describing students' and teachers' engagement in online learning. The comparison plot shows a significant shift along the x-axis in the network connections in synchronous and asynchronous online activities. The individual and combined models (Figures 1-3) elucidate that students make cognitive connections in both modes of learning, but teacher feedback is more evident and varied during synchronous sessions. The first quadrant of the projection space (upper right) shows the concentration of the kinds of feedback teachers provided. The lines on the right side of the y-axis show that teachers give more affective, corrective, informative content, and reflective feedback for every cognitive engagement of the students. Also, it is interesting to note that students engage in synchronous sessions by connecting, extending, and, at times, not responding. The following are some examples of actual engagements of students and teachers in synchronous and asynchronous sessions:

Table 7

Excerpt of Connecting- Affective Corrective Engagements in Synchronous Classes

Line	Participant	Utterance	Type of Engagement
1975	Student 5 - HUMSS	They are connected to each other. Maybe one variable is controlled by the other?	Connecting
1976	Teacher	Okay. Nice point. Yes, you are raising your hand, Student 6.	Affective
1977	Student 6- HUMSS	When one variable changes, the other variable changes too.	Connecting
1978	Teacher	Alright. Good answer. That is right. To understand the concept of correlation, let us relate it to real-life situations...	Affective- Corrective

In Table 7, the excerpt from the metadata illustrates incidences of connecting affective and corrective nodes between teachers and students, which transpired to be the most observed engagement in synchronous classes. Summarized frequencies presented in Tables 9 and 10 reveal that connecting (43.48%), affective (25.60%), and corrective (19.80%) are prominent in isolation. When paired, connecting-corrective is the most prominent occurrence of engagement among teachers and students based on the visual model in Figures 1 and 2 and statistical information in Table 6.

The ENA model uncovers students' inclination to connect during synchronous sessions despite their physical distance from their teachers and classmates. Line 1975 shows that Student 5 from HUMSS attempted to connect by responding to the prompt about what it means when two variables are said to be correlated. This is followed by affective feedback from the teacher. The actual utterances are numbered. Line 1977 demonstrates Student 6 from HUMSS making similar connections with the teacher, providing affective-corrective feedback. The entire metadata and the ENA models highlight this engagement in synchronous classes. The interview data from students and teachers further explain this engagement. "One participant shared that they have a moderate level of engagement in synchronous classes. They tried their best to connect with their teachers by answering their questions and sharing their opinions when they asked for" (HUMSS Student 3).

Another student also revealed that they connect with their teachers the way they used to connect with them during face-to-face classes. Some students are very engaged in synchronous classes even if they are uncertain about the answers to teachers' questions. "Sometimes, I feel like synchronous class looks almost the same as face-to-face class because I can notice that we are doing our best to respond to our teachers even if we are unsure of our answers…" (Student 5, ABM).

When the interview participants were asked how teachers responded when they tried to connect with the lesson and their teachers, they said their teachers usually encouraged them to recite and participate by recognizing their answers and giving compliments. This made the students participate even more. One of the student participants shared, "Our teachers motivate us to recite. I noticed they always have something good to do, even if our answers are incorrect. We are more comfortable making connections because our teachers will appreciate our answers" (Student 2, STEM).

The teacher-participants also reveal interesting insights about the feedback they give during synchronous classes. They value students' engagement, even in the simplest form, because students' provocation to be passive is more likely in the online setup. They highlighted the value of giving affective and corrective feedback in synchronous classes. "Feedback that appeals to students' emotions is more impactful. Simple phrases and statements such as 'thank you for your participation' or 'nice answer' are very crucial in online learning" (Teacher 2).

Table 8

Excerpt of Prompt-Emancipating Engagements in Asynchronous Classes

Line	Participant	Utterance	Type of Engagement
908	Teacher	Analyze and describe how each text presents, organizes, and links ideas and how effectively each text uses language and follows mechanics (e.g., spelling, punctuation, and abbreviation.) Cite specific examples in your explanation.	Prompt
909	Student 12-STEM	I think that the text comes from a very personalized opinion about a website that the writer was very fond of, and struggles to clarify the bold understanding of what they were trying to get at but still provides ideas, like text 1, but just looks pretty surface level and could get somewhere but just struggled to put it together.	Emancipating
1070	Teacher	Analyze and describe how each text presents, organizes, and links ideas and how effectively each text uses language and follows mechanics (e.g., spelling, punctuation, and abbreviation.) Cite specific examples in your explanation.	Prompt
1071	Student 20-HUMSS	The author couldn't achieve ideas that are logically and accurately arranged. The text had no separate paragraph for the introduction, body, and conclusion, making it difficult to organize the author's thoughts.	Emancipating

According to the students, the asynchronicity of learning activities gives them time to reflect on the lessons and make substantial engagements with their teachers. Some students perceived real-time communications in synchronous classes as quite threatening as they needed to give immediate responses, like face-to-face engagements. The more flexible opportunity to engage oneself in asynchronous prompts allows some learners to develop higher levels of cognitive engagement. The interview data supports these arguments. One participant shared “I am not confident to respond abruptly when asked, so I am more comfortable engaging offline because I am given time to compose my answers” (Student 5). Another student supports this: “Because of the nature of offline tasks, I have more time to apply critical thinking skills and express my personal opinions without fear of being judged by my classmates in synchronous classes” (Student 7).

Students who may be introverted but are diligent and committed can reap benefits in asynchronous classes. Some students need more time to activate their cognitive processes. During offline activities, they were given significant time to compose their submissions, reflect on improving their submissions, and engage more actively. Offline tasks were seen to be less threatening to students in general.

The teacher-participants admitted they fell short in giving feedback to students' submissions and inquiries offline. Participating teachers shared that they did their best to provide feedback to students' cognitive engagements through the school's learning management system and social media. However, they recognize the possibility of not providing prompt, specific, and encouraging feedback. These interview data are very evident in the presented ENA models, where the teachers seem to struggle to provide varied, informative, and reflective feedback that can empower students in asynchronous activities. This is explained by one of the teacher-participants.

> We value the importance of providing feedback to students. We check students' work, but as much as we want to be generous in providing detailed, comprehensive, and reflective feedback, the amount of work we do offline, like checking students' submissions, is tremendous. (Teacher 2)

Discussion

The ENA model demonstrates that teachers' and students' engagements differ from synchronous and asynchronous sessions in an online research course. The same findings can be extracted from the study of Yuyun (2022) and Chafouk and Marjanei (2024), where higher engagements were found in synchronous sessions. It shows that when students try to connect with the content, teachers provide affective feedback mainly. Arapakis et al. (2008) underpin this connection between students and teachers inside the classroom, where affective feedback can motivate students to seek information, such as connecting with the teachers. However, while affective feedback positively affects students' engagement, feedback targeting cognitive dimensions is more valuable. Lu and Law (2012) argue that affective feedback fails to increase task engagement because it usually contains little task-related information.

The Epistemic Network Analysis reveals insightful patterns of teachers giving more consistent and varied feedback in synchronous sessions than in asynchronous sessions. Looking closely at the observed engagement in asynchronous sessions, the ENA models illuminate nodes that occur in temporal sequence. The models show that prompt-connecting, simply agreeing-affective, and prompt-emancipating are dominant nodes. The occurrences of teachers' prompts in asynchronous classes are expected since students' learning activities to reinforce lessons learned in synchronous classes are given offline. The thick lines on the left side of y-axis in the model reveal that the co-occurrence of teachers' prompts and students' connecting appears numerous times. However, it is interesting that the teacher's feedback on students' cognitive connections in asynchronous sessions is not as evident as in the synchronous sessions. This affects teachers' presence in asynchronous sessions, where teachers are expected to provide stylistic and substantive feedback to students (Watson et al., 2023).

The ethnographic data collected and analyzed in the present study reveal analogous results with the existing literature. The multi-case evaluation study about asynchronous courses of Garrison and Innes, as cited in Malik et al. (2017) showed that student participants in asynchronous sessions sought the content uploaded by their teachers and tried to engage themselves in meaningful learning tasks. Also, Pappas (2015) elucidated that some introverted participants may feel uncomfortable engaging in live online discussions dominated by some assertive peers. The modality of asynchronous classes helps learners eliminate social anxiety and make meaningful engagements, such as *emancipating*. These parallel findings fortify students' opportunities as they make higher cognitive engagement in offline tasks.

Previous studies also underpin the observed teachers' disinclination in providing feedback in asynchronous classes in the past years. Zhohar and Smith, as cited in Leibold and Schwarz (2015), stressed that students complain that teachers do not provide enough positive feedback in online courses. Pappas (2015) underscored that instant feedback is one of the disadvantages of asynchronous learning. Also, Borup (2021) revealed that providing feedback via text is time-consuming, which causes feedback delays and forces teachers to give generic feedback. Feedback should not be delayed; assignment feedback is best returned to learners in less than one week so that students can be informed about the learning areas that need improvement before the next course assignment (Leibold & Schwarz, 2015). Comparing asynchronous and synchronous engagements of teachers and students is particularly important for providing insights toward the design of learning environments, like in the context of online research courses (Riel et al., 2022).

Limitations

Understanding the study's limitations can help the readers interpret the findings with appropriate caution. First, the captured engagement of teachers and students occurred in online research courses for senior high school students that used a teleconferencing platform for synchronous sessions and a learning management system for asynchronous sessions. The features of the teleconferencing platforms (e.g., chat functions and screen sharing) might have facilitated certain types of engagement while hindering others. Second, the courses focused on research writing that might explain the engagement between teachers and students. Third, while using ENA maximizes the rigor of both quantitative and qualitative methods, selecting predetermined codes of teachers' feedback and students' cognitive engagement might have limited the captured spectrum of engagement. There is no need for a larger sample size, as ENA studies work well with a small sample size. Future researchers may attempt to understand better the subcomponents of the significant predictors of students' cognitive engagement in online learning so that schools may further enhance students' self-regulated behaviors, train teachers to improve their virtual presence, and improve their engagement in online learning.

Conclusions and Implications

In synchronous sessions, the epistemic frame of students' engagements provides anecdotes of students trying to connect and extend their ideas related to the course with their teachers. The ENA models have proven that the participating teachers provided varied feedbacking styles and content ranging from affective, corrective, and informative content. While reflective feedback is essentially less evident, it shows that online teachers are responsive to the cognitive engagements given by students during live sessions. Thus, the epistemic frame among students and teachers shows that students attempt to respond and connect that may or may not lack scholarship (connecting), with evidence of interest in asking further questions along the same line of argument (extending) and teachers providing combined affective and cognitive-related feedback. The epistemic frame suggests that direct and real-time engagements offer teachers more opportunities to give their students meaningful feedback that can increase their overall connection to the course, genuine engagement, and academic achievement.

In asynchronous sessions, the epistemic frame reveals an interesting structure of students' cognitive engagement ranging from simply agreement (low), connecting (moderate), and emancipating (high), with "connecting" being the most prevalent response to teachers' prompts. Looking more closely at the ENA models using an epistemic lens unveils that teachers' feedback is limited during asynchronous sessions, mostly constrained to affective and informative content. Thus, the epistemological frame of engagement in asynchronous sessions shows that students flexibly demonstrated varying cognitive responses, from mere agreement to mastery of the content and skills by applying critical thinking and making personal connections. At the same time, teachers' feedback is less evident and limited to affective and informative content.

As a whole, ENA was found to be useful in modelling the differences in the structure of engagement among teachers and students. Different network models were created, and visual plots and summary statistics proved useful in quantitizing, transforming, and analyzing qualitative data. ENA confirms the difference in the structure of engagement among teachers and students, where teachers made more frequent and substantial feedback. The use of mixed-methods approach to analyzing cultural data, such as students' and teachers' engagement in online learning, proves to be promising in processing, describing, and analyzing educational data.

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