INVESTIGATING SOCIAL PRESENCE IN COLLABORATIVE KEYS FOR ASYNCHRONOUS COURSES

A Thesis

presented to

the Faculty of California Polytechnic State University,

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Statistics

by

Lily Painton Cook

June 2025

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COMMITTEE MEMBERSHIP

TITLE: Investigating Social Presence in Collaborative Keys for Asynchronous Courses

AUTHOR: Lily Painton Cook

DATE SUBMITTED: June 2025

COMMITTEE CHAIR: Anelise Sabbag, Ph.D.
Professor of Statistics

COMMITTEE MEMBER: Samuel Frame, Ph.D.
Professor of Statistics

COMMITTEE MEMBER: Beth Chance, Ph.D.
Professor of Statistics

ABSTRACT

Investigating Social Presence in Collaborative Keys for Asynchronous Courses

Lily Painton Cook

Asynchronous virtual courses have become increasingly popular in the years following the global Covid-19 pandemic. These courses, with no set meeting schedule, offer flexibility to both students and instructors, but pose challenges for developing a collaborative learning environment. The Community of Inquiry framework (Rourke et al., 1999) identifies three essential components in an online course necessary to foster a collaborative environment- teaching presence, cognitive presence, and social presence. Social presence is especially impacted in asynchronous learning settings, which presents challenges for the students to display their personalities and connect with the community. This study investigates Collaborative Keys (CKs), structured collaborative assignments given in an asynchronous class, to help remedy the lack of social interaction. Data were collected on Cal Poly students in an introductory statistics class in Winter 2023 on various indicators of social presence in the assigned CKs. This research examined the presence of social interactions over the duration of a quarter and their changes over time. Overall, high levels of social presence were observed in the CKs, suggesting they were successful in cultivating student engagement. Additionally, the relationship between social presence and academic performance in the course was investigated. Results include a significant positive association between the rate of cohesive social presence and student performance and a significant negative association between the rate of self-disclosure and student performance. These results will inform pedagogical approaches that incorporate collaborative learning into virtual environments and improve students' experiences in asynchronous modes of instruction.

ACKNOWLEDGMENTS

I would like to give thanks to my advisor Dr. Anelise Sabbag for her guidance and support with this thesis and with life. Without her, I would not be where I am today. I would also like to thank Dr. Samuel Frame and Dr. Beth Chance for being part of my committee and providing invaluable guidance. Lastly, I would like to thank my family and friends for their consistent support through my education. This research was made possible by the William and Linda Frost Fund and their generous contributions.

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INTRODUCTION

Virtual (online) learning has been around for decades, allowing students to engage with educational content outside of traditional classrooms. When the global COVID-19 pandemic occurred, virtual learning became a necessity as the ability to meet face to face was severely limited. In the years following the pandemic, virtual learning, especially asynchronous courses with no set meeting time, remains a viable but understudied educational approach in higher education. This mode of learning has many benefits for both students and instructors- a flexible schedule, the ability to review material at an individual pace, and increased learning accessibility for students with disabilities (Sabbag et al., 2025).

However, asynchronous learning is not without its challenges. Notably, the lack of opportunity for face-to-face interactions provides a challenge for students to create meaningful relationships with their peers and instructor. The absence of personal connections can hinder building a collaborative learning environment, which is an important component to a successful educational experience (Prince, 2004).

To address these issues, the Community of Inquiry (CoI) framework (Rourke et al., 1999) proposes a model for successful online learning environments. The framework identifies three essential elements: teaching presence, cognitive presence, and social presence. Social presence, defined as "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities" (Garrison,

2009, p. 352) is particularly impacted by online learning due to the lack of real-time interaction.

This study focuses on enhancing social presence in asynchronous learning environments. Specifically, it examines the role of Collaborative Keys (CKs), a type of assignment designed to foster peer interaction, in promoting social presence. This thesis aims to understand social presence in CKs and its relationship with student performance in an asynchronous learning environment. To investigate this, data were collected from students' CKs in an introductory statistics class at Cal Poly on various indicators of social presence.

The upcoming sections are organized as follows: Chapter 2 delves into the background of this research, including the CoI framework and previous findings; Chapter 3 details the methods used to collect and analyze the social presence data; Chapter 4 presents the results of this analysis; and Chapter 5 concludes with final remarks, implications of results, and recommendations for future research involving CKs.

Chapter 2

BACKGROUND AND LITERATURE REVIEW

2.1: Community of Inquiry

For this project, the Community of Inquiry (CoI; e.g., Rourke et al., 1999; Garrison et al., 2000, 2001; Akyol & Garrison, 2013) framework was selected. This research-based framework was designed for computer-based discussion forums in online learning environments, and it has been used by many education researchers (e.g., Burnham, Blankenship, & Brown, 2023; Popescu & Badea, 2020; Guo et al., 2021; Waddington & Porter, 2021). Some of these researchers have found that implementing CoI increases student learning, measured through satisfaction and student performance. In addition, students tended to engage more meaningfully with course content under this framework. This framework has been investigated in multiple settings, including in-person and online courses, as well as online conferences. CoI takes a holistic approach to measuring various aspects of participation in online courses. The three main pillars are social, cognitive, and teaching presence (see Figure 1):

- Social presence (SP) is defined as "the ability of participants to identify with the community (e.g., course of study), communicate purposefully in a trusting environment, and develop interpersonal relationships by way of projecting their individual personalities" (Garrison, 2009, p. 352).

- Teaching presence is the design, facilitation, and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes (Anderson, Rourke, Garrison, & Archer, 2001). In

the case of an asynchronous classroom, this includes both indirect and direct interaction with both the professor and the course materials.

- Cognitive presence is the extent to which learners are able to construct and confirm meaning through sustained reflection and discourse (Garrison, Anderson, & Archer, 2001)

For the purpose of this study, the social presence aspect is the focus and is broken down further into three different categories: affective, interactive, and cohesive. More information about these categories will be provided in the Methods Section, 3.3. The next section discusses how the Social Presence category of the CoI has been used in research.

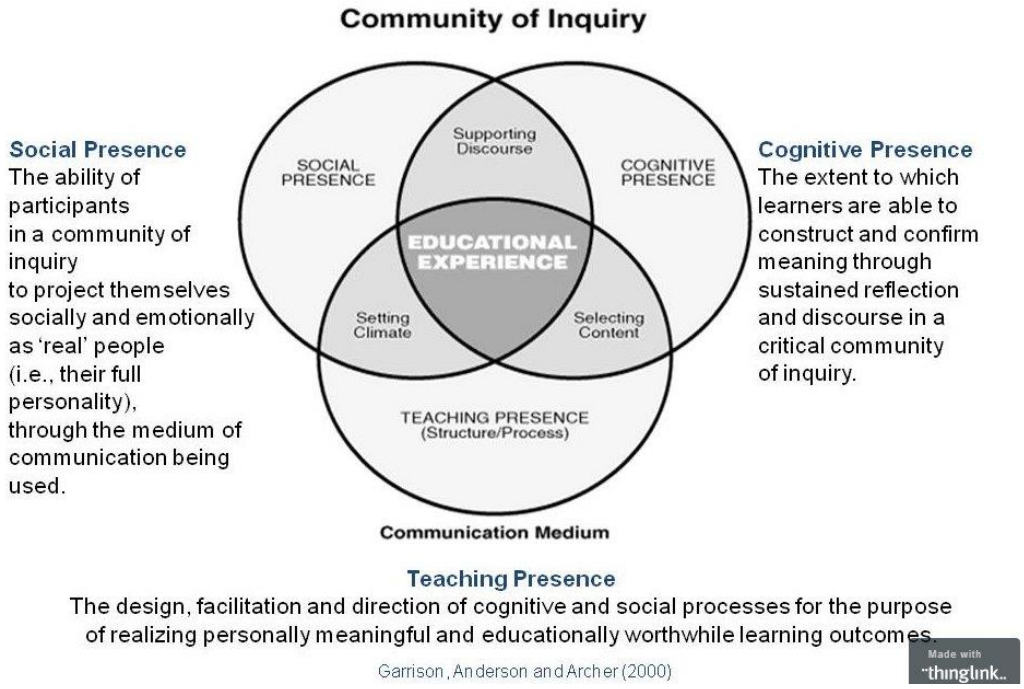


Figure 1: The breakdown of CoI framework and presences (Garrison, Anderson, and Archer, 2000)

2.2: Social Presence

The social presence aspect of the CoI in higher education has been greatly researched since its proposal in many different settings including in-person classrooms (e.g., Guo et al., 2021; Popescu & Badea, 2020), conferences (Waddington & Porter, 2021), and asynchronous classes (e.g., Weidlich et al., 2023; Richardson et al., 2017). Different authors and researchers define social presence in various ways, but all definitions capture the same concept of students' ability to project themselves and their personality in the classroom setting. For example, Waddington & Porter (2021) defines social presence as "The degree in which people are perceived as real and contribute purposefully within the online community." Recently, research has been done into the use of various social media platforms (e.g., WeChat, Twitter, blogs) to assist in students' communications in online settings and it has shown encouraging results (e.g., Guo et al., 2021, Popescu & Badea, 2020). For instance, Weidlich et al. (2023) report that students' perceived social presence is largely associated with their perceived learning in the course. Additionally, Guo et al. (2021) found indicators of social presence in the majority of social media messages made outside of the classroom. Many studies have shown that social presence is beneficial to students' experience in the classroom (e.g., Waddington & Porter, 2021, Richardson et al., 2017; Weidlich et al., 2023), but only a few have looked into the impact of social presence on academic performance (Guo et al., 2021). Guo et al. (2021) showed preliminary evidence that certain aspects of social presence are positively associated with student performance, which encourages further research. In addition, Richardson et al. (2017) found positive correlations between both social presence and student-reported

perceived learning, and between social presence and student-reported satisfaction in a meta-analysis of 26 articles regarding social presence in asynchronous classes.

2.2.1: Encouraging Interaction in Online Courses

Opportunities for students to interact with each other and work collaboratively can help create a sense of community and facilitate the learning process (Everson & Garfield, 2008; Mills & Raju, 2011). Even in asynchronous online courses, students can construct knowledge together as they interact with other students (and with the professor). However, one of the biggest challenges in online teaching is creating the key elements of cooperative learning found in a well-designed face-to-face environment and assessing the extent to which the design is meeting intended goals.

2.2.2: Discussion Forums

One popular pedagogical approach to develop community and encourage active learning is the online discussion forum (e.g., Everson & Garfield, 2008; Schmid, 2013; Grandzol, 2004; Summers et al., 2005). The research literature reports the benefits of discussion forums which include the opportunity for students to actively engage the course material, collaborate with other students (and instructors), and construct knowledge through written conversations (de Lima et al., 2019; Nandi et al., 2012, Balajic & Chakrabarti, 2010, Brower, 2003; Thomas, 2002). Besides the convenience and accessibility, the asynchronous nature of online discussion forums gives students time to really think and reflect before providing an answer, an advantage over face-to-face settings with group or class discussions (Balajic & Chakrabarti, 2010; Garrison et al., 2000).

Despite these advantages, discussion forums are often an unsatisfactory method for creating student engagement in asynchronous online courses. Burnham, Blankenship, and Brown (2023) describe how, even in a well-designed introductory statistics course, student engagement in discussion forums was not ideal. Students rarely responded to other students, even after adding an incentive to participate. Some of the challenges using discussion forums reported by de Lima et al. (2019) are identified as accompaniment difficulty, structural difficulty, and motivation difficulty.

- *Accompaniment difficulty*. It can be incredibly challenging and time consuming for an instructor to consistently monitor threads and provide quality feedback and guidance/feedback.

- *Structural difficulty*. If many open-ended questions are provided in the forum, the resulting large number of students' posts can be hard to follow, organize, and grade. de Lima et al. (2019) reported that the discussion can become a very long and chaotic list of posts. This can be hard to navigate and may actually harm students' interactions as they lose track of to whom they are responding.

- *Motivational difficulty*. Students disengage from the forum when there is not much instructor mediation or when the forum's features seem outdated compared to current social media technology.

These and similar problems with discussion forums are also reported by Herman & Nilson (2018), Rabbany et al (2014), De Wever et al. (2006), Pena-Shaff and Nicholls (2004), Berge and Collins (1995), Harasim (1990), Hiltz (1990), and Levin et al. (1990).

Based on the research in online teaching and learning, there appears to be several factors that can influence the effectiveness of discussion forums, such as the structure of the course and student attitudes. Tawfik et al. (2017) find that lower levels of student-to-student interactions may result from the course design. For instance, Lucas et al. (2014) and Hou et al. (2009) indicate students are disinterested in discussion forums that are not required. Student engagement and interaction is derived from the class community and how well students know each other. Tawfik et al. (2017) argue that smaller group sizes are needed to increase student student-to-student interaction, and that social presence and a sense of community are positive consequences of working in smaller groups. Finally, a lack of prior knowledge also seems to hinder student-to-student interactions by reducing learners' confidence and ability to contribute meaningfully to discussions (Tawfik et al., 2017).

The findings above suggest that discussion forums support student learning only in very particular, highly-structured conditions—conditions that are present and that are mostly captured in *cooperative learning.* The following section presents a novel pedagogical tool, Collaborative Keys, as an alternative to discussion forums. The Collaborative Keys are based on cooperative learning theory and address many of the limitations of discussion forums.

2.2.3 Collaborative Keys

As described in Sabbag and Frame (2021) and Sabbag et al. (2025), Collaborative Keys (CKs) are assignments that are administered to students in an asynchronous classroom as a way for students to work together on statistical questions. CKs are designed for

asynchronous classrooms and the unique challenges that come along with this setting, mainly the lack of student-to-student interaction and lack of engagement with the course. The CK is given as a supplement to normal homework rather than replacing it. A CK is a shared Google Doc that has a subset of the homework questions pre-populated into it. The questions chosen for the CK cover the most important statistical topics/ideas in the homework assignment. The goal of this assignment is for a group of students to create an "answer key" of correct solutions that they can refer to throughout the quarter as necessary. The CKs allow multiple students to collaborate and share ideas in the document when they work on the course material asynchronously.

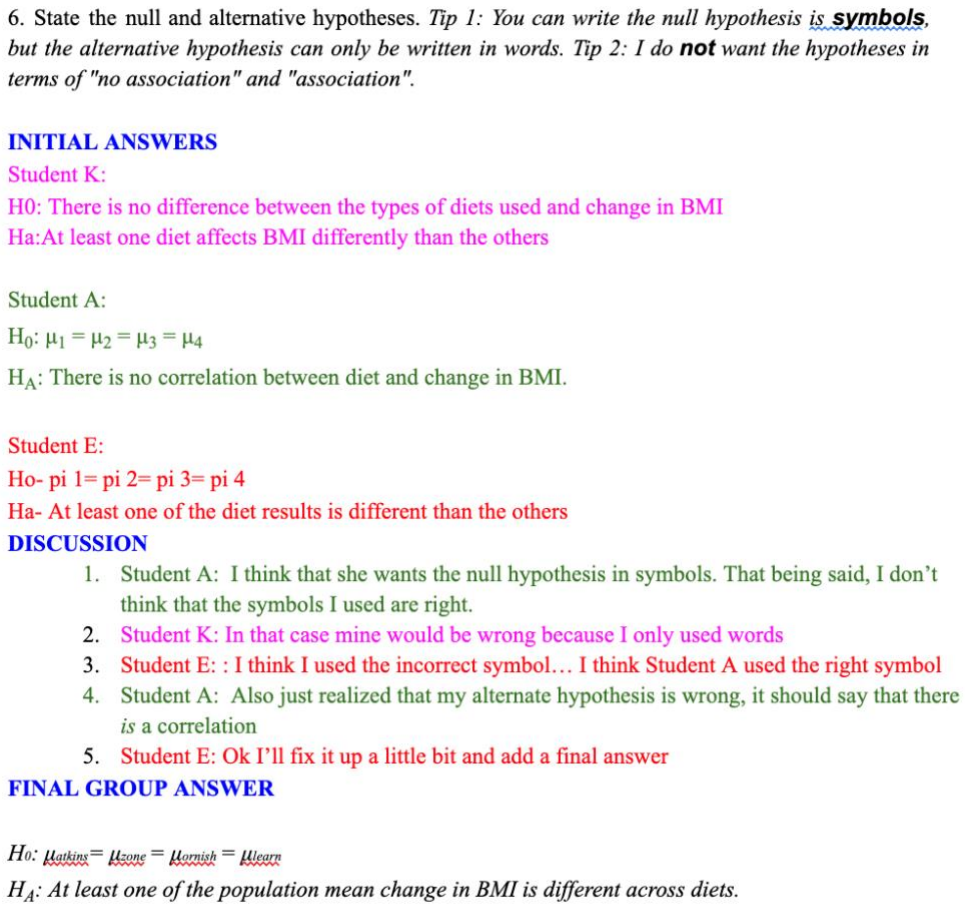
Before working on the CK, students are first assigned homework to be completed and submitted individually. These submissions are graded on completion. Then, in groups of 3-4, students complete the CKs, going through three phases of work:

1. **Initial answer** (completed individually; one per student): Students first include their individual initial answers, copying and pasting from their homework assignment. This is based on their current understanding of the material.

2. **Discussion** (completed as a group; one or more per student): After all students have included their answers in the initial answer section, they discuss them as a group, covering any mistakes or corrections that need to be made and reflecting on their learning process, ultimately coming to a consensus on a final answer to be included. Each student is required to include at least one comment on each question. This is where the social interactions will occur.

3. **Final Group Answer** (completed as a group; only one per group): The group decides on a final answer, determined to be the correct solution to the problem. This is included in the final submission and graded for correctness by the instructor.

The three sections (initial answer, discussion, and final answer) are distinctly labeled in the assignment, ensuring they are easily identifiable to the students and instructor. This helps to hold students accountable. An example of a CK question is shown in Figure 2.



6. State the null and alternative hypotheses. *Tip 1: You can write the null hypothesis is* ***symbols****, but the alternative hypothesis can only be written in words. Tip 2: I do* ***not*** *want the hypotheses in terms of "no association" and "association".*

INITIAL ANSWERS

Student K:

H0: There is no difference between the types of diets used and change in BMI

Ha:At least one diet affects BMI differently than the others

Student A:

H_0: $\mu_1 = \mu_2 = \mu_3 = \mu_4$

H_A: There is no correlation between diet and change in BMI.

Student E:

Ho- pi 1= pi 2= pi 3= pi 4

Ha- At least one of the diet results is different than the others

DISCUSSION

1. Student A: I think that she wants the null hypothesis in symbols. That being said, I don't think that the symbols I used are right.
2. Student K: In that case mine would be wrong because I only used words
3. Student E: : I think I used the incorrect symbol… I think Student A used the right symbol
4. Student A: Also just realized that my alternate hypothesis is wrong, it should say that there *is* a correlation
5. Student E: Ok I'll fix it up a little bit and add a final answer

FINAL GROUP ANSWER

H_0: $\mu_{atkins} = \mu_{zone} = \mu_{ornish} = \mu_{learn}$

H_A: *At least one of the population mean change in BMI is different across diets.*

Figure 2: Example of CK, with question, initial answer, discussion and final group answer sections

The structure of the CK as described above is intentionally based on many research-based principles of active and cooperative learning, such as positive interdependence and individual accountability (Johnson & Johnson, 2009).

Sabbag et al. (2025) investigate the use of CKs in an asynchronous statistics education setting, building on previous research (Sabbag & Frame, 2021): An initial version of CKs was given as a class-wide assignment. This design resulted in many student-instructor interactions but only a few student-student interactions. This design was revised to the current version, with small groups of 3-4 students, yielding less reliance on the professor and more instances of student-student interactions. In total, this revised design returned promising results including more social presence in students' interactions. Sabbag et al. report the need for further investigation into CKs, specifically regarding social presence over time, student group differences, and relation to academic performance. This study addresses this need.

Chapter 3
METHODS

3.1: Data Collection

Data on Collaborative Keys assignments was collected in an introductory statistics course at Cal Poly during the Winter 2023 quarter. Students in this course were assigned one to two CKs per week, along with their corresponding homework assignments, resulting in a total of ten required and one optional CK. The homework assignments had due dates prior to the CKs being assigned. Students additionally had a deadline to input their initial answer in the document to ensure groups had sufficient time for their discussion before the due date. All students were asked to voluntarily provide their consent to participate in the study at the end of the quarter. If a student did not give consent, their work was not included in the research. A total of 61 students in 17 groups were enrolled in this class, with 57 students giving consent to participate in the study. The sample was reduced to 33 students in 9 groups, as only groups in which all students gave consent to participate in the study were considered. This resulted in a total of 90 CKs.

3.2: Indicator Coding

To investigate students' social interactions in the CKs, students' answers were categorized according to the social presence framework from the Community of Inquiry (Rourke et al., 1999). Categories of social interaction and indicators of the categories were determined based on Rourke et al. (1999). The three main categories within the social presence aspect of this framework are affective responses, interactive responses, and cohesive responses. The indicators for the *affective* response used are expression of

emotion, use of humor, and self-disclosure. The indicators for the *interactive* responses are quoting others, expressing agreement, asking questions, answering questions, complimenting, and expressing appreciation. The indicators for the *cohesive* responses are use of vocatives, phatics, and group inclusive pronouns. Some modifications were done to the framework so it would be suited for CKs.

The structure of the CK assignment encourages students to ask and respond to questions amongst themselves, so it was deemed necessary to add two new categories for both asking questions and answering questions. The answering question category is a new category, not based on Rourke et. al (1999) but is similar to the proposed category of continuing a thread, which was removed as it does not apply to this assignment. In addition, the complimenting and expressing appreciation categories were merged because they had a fair amount of overlap (i.e., compliments often were followed by an expression of appreciation or also could be considered expressions of appreciation in their own right), and many student responses used the two interchangeably.

Using this framework, the process of coding began by reading each individual response in each assignment and specifying in a spreadsheet whether the response contained any of the eleven indicators of social presence with a 0 for no indicator present and a 1 for indicator present. An example of coding is displayed in Figure 3 and Table 1. At the beginning of this process, this was a collaborative effort by the researcher and a student researcher. Initially, the two collaborators individually coded a CK assignment independently, with no discussions and continuously referring to the definition of each indicator throughout the coding process. After the individual coding was done, they met, compared the coding, discussed disagreements and came to a consensus. This process

was repeated until a high achievement rate was obtained (around 95% overall after 6 CKs were coded independently) - see Table 2. The research student individually coded the 84 remaining assignments. Though this process continued as an individual task for all remaining assignments, the research student and the researcher discussed when necessary.

Student V: Because of my prior incorrect answer, this led me to another wrong conclusion that it was a type I error. I think Student A is right that we could be making a type II error. According to the wrap-up video, because we could have failed to reject the null, but the null could have been false, this leads us to a type II error.

Student D: I am not too sure about my answer, but I believe that it is a type II error because the P-value was a little easy to mess up for me

Student A: I think it is a Type II error because I failed to reject the null hypothesis. So, since I failed to reject the null hypothesis, the null could have been false. Should we go with a Type II error?

Student V: Yes I agree, that sounds good!

Figure 3: Example of student interaction in a CK, highlighted phrases correspond with the codings in Table 1

Table 1: Example of indicator coding for social presence corresponding to the interactions in Figure 3

Name	SP_ appreciation	SP_ vocatives	SP_ agreement	SP_ pronouns	SP_ self_discousure	SP_ ask_question	SP_ ans_question
Student V	1	1	0	1	1	0	0
Student D	0	0	0	0	1	0	0
Student A	0	0	0	0	0	1	0
Student V	0	0	1	0	0	0	1

Throughout this process, a spreadsheet was kept with the indicators used to determine social presence and definitions and examples of student responses that fit into the categories. This helped establish the high agreement rate between the two collaborators. This spreadsheet was updated throughout the coding process when unique student responses that fell into the categories were found, and when an example was discussed and determined to be a proper indicator (see Table 3). This process led to a large and complete dataset with 2,735 observations of 16 variables, with each unit of measurement corresponding to a student response in the CK. The 16 variables included all social presence indicators and other identifying information such as student identification, assignment number, group number, and question number.

Table 2: Agreement rates on the 6 CK assignments coded independently

CK	Group	Number of Codes	Number of Agreements	Agreement Rate
1.2	Group 1	517	488	94.4%
1.2	Group 4	495	471	95.2%
1.2	Group 6	484	461	95.2%
2.2	Group 14	231	218	94.3%
2.2	Group 15	253	247	97.6%
2.2	Group 17	363	340	93.7%
	TOTAL	2343	2225	95%

Table 3: Indicator coding scheme for social presence

Indicators	Definition	CK example
Affective		
Expression of emotion	Conventional or unconventional expressions of emotion, includes repetitious punctuation, conspicuous capitalization, emoticons.	emoji, lol, OPS, woot woot, wow, "I am glad", "I appreciate", haha, oh shoot, " !!! " YAY, "sorry", "oooohhhhh"
Use of humor	Teasing, cajoling, irony, understatements, sarcasm.	lol, haha counts as emotion and humor
Self-disclosure	Presents details of life outside of class or expresses vulnerability.	"I honestly do not really understand this question", "I don't know", "Not sure", OOPS, "I did this one wrong," "I was close" (any EXPLICIT acknowledgement of a mistake). "*I might* have made a mistake" still counts as being vulnerable; "make sure we did not miss anything".
Interactive		
Quoting from others' messages	Using software features to quote others entire message or cutting and pasting selections of others' messages	
NEW FOR CK: Asking questions	Students ask questions of other students or the moderator.	Usually if a question mark it's a question even if the grammar isn't technically a question. The other way around also is a question (right grammar and no "?")
NEW FOR CK: Answer questions	Students answer a question that was asked	We only categorize this if there is a question that was asked.
Complimenting, expressing appreciation (saying something positive about someone's answer).	Complimenting others or contents of others' messages.	"Good job" tentatively is always considered expressing appreciation. "Yours is the best" or "Yours is more accurate" is a compliment. "You're right" is a compliment too. "Nice" We are not categorizing as a Compliment if it is a whole group comment
Expressing agreement	Complimenting others or contents of others' messages.	"Great." "Solid" "I agree"; "Sounds good"; "yep"; "yes"; "Okay"; "My answer is wrong **too**"; "Looks good"; "That makes sense to me." I did this **as well**, our answers are **similar,** good point, "^" (agreement with prior comment) **Note: "our answers are correct" is not agreement**
Cohesive		
Vocatives	Addressing or referring to participants by name.	
Addresses or refer to the group using inclusive pronouns	Addresses the group as we, us, our, group	We are categorizing all "we" even if it refers to math/stat ideas and conclusions, "Let's" is Let Us
Phatics, salutations	Communication that serves a purely social function; greetings, closures.	thanks to a compliment, "no problem", "It is ok...", "... thank you for your help/for pointing that out", "no worries". "hi/hello/hey", "sorry" NOT phatics is: Hmmm

3.3: Analysis

Because this is the first research paper investigating students' social interactions through the CK assignments and using the CoI framework, both exploratory and more formal analyses were completed to better understand the data and evaluate the relationship between social presence and performance.

Exploratory analysis helped us to gain deeper insights into the data, including identifying social presence instances for each student, identifying students who potentially behave differently than other students, examining the distributions of each category of social presence and potential relationships between them. This step, together with educational theory, is important to inform model creation. After this, more formal analysis with additional performance data can be completed to identify and quantify potential relationship between social presence and course performance. The following subsections of analysis include data cleaning, variables used, descriptive associations, and inferences.

3.3.1: Data Cleaning

The data set used in this study was developed by the author who ensured completeness. Therefore, only minimal data cleaning was necessary for this analysis. The cleaning process included the creation of new variables using the data to facilitate comparisons and removal of data in which there was inconsistent participation of students within groups. These instances will be discussed further in the following section.

3.3.2: Variables

The numerous variables and student grouping factors (such as group and CK assignment number) have complex relationships that are necessary to be explained as part of this analysis. First it is important to understand the composition of each student group and the timing and composition of each CK.

The CKs were not identical throughout the quarter. The number of questions within the CK ranged from six to ten, as seen in Table 4. Additionally, the number of CKs assigned to the students each week were not the same, also reflected in Table 4.

Table 4: Breakdown of CK assignments

Collaborative Key	Number of Questions	Week of Quarter
1.2	9	2
2.1	9	3
2.2_ 3.1	7	3
3.2	9	4
5.1	8	6
5.2	8	6
7.1	7	7
8.1	6	8
9.1	7	9
10.1	6	10
Total		
10	76	8

The number of questions in each assignment is an important factor to take into consideration as students are expected to respond in the discussion portion of each question at least once. This means that it is expected that in a CK with more questions there will be more student responses. The adjustments made to account for this will be discussed later in this section.

In addition to differences among assignments, there were differences in the number of students in each group, with some groups changing over the quarter. This information can be seen in Table 5.

Table 5: Breakdown of assignment groups

Group Number	Number of Students	Changes
1	4	Additional student in CK 1.2
4	4	None
6	4	Split into two groups in CK 10.1
7	4	None
9	3	None
11	3	None
14	3	None
15	4	Student joins group in CK 5.1 and remains in group for the quarter
17	4	None

Similar to the number of questions in a CK, the number of students in a group impacts the number of responses in the discussion part of the CK. Each student is expected to respond to the discussion at least once for each question in the assignment, meaning a group with four students should have more discussion posts than a group with three students. Additionally, students changing groups creates an inconsistency in students' interactions which makes comparisons difficult. Thus, for the analysis in which groups and assignments were compared, Group 15 was removed along with CKs 1.2 and 10.1. This way, all groups included in the analysis remained constant through all assignments, with the exception of students failing to complete an assignment but remaining in the group.

First, student-level variables were created. The total number of instances each student displayed each of the 11 categories of social presence within their responses to the discussion was calculated for the whole quarter across all CKs. The same was computed

for each of the three primary categories of social presence (affective, cohesive, and interactive). Descriptive measures of center and variability were calculated for these totals. Similar "total" variables were created for overall social presence (e.g., total social presence instances through the quarter across all 11 categories) and number of posts (total number of posts in the discussion sections across all CKs). A variable recording the students' most used social indicator was created based on these totals. For all three primary categories of social presence and for two indicators of interest (self-disclosure and agreement), proportions of instances displaying such indicators were created for each student by taking the total instances of the indicator of interest and dividing by the total overall social presence.

Next, group level variables were created. To do this, the students were sorted into their group, and the previously mentioned student-level variables were averaged across the group. Group totals for the 11 indicator variables, three primary categories of social presence and number of posts were also recorded.

Since the number of questions in each assignment are inconsistent through the quarter and the number of students in each group vary, it is important to adjust before comparing interactions across assignments. To do this, two types of variables were created for total social presence and the three categories of social presence (affective, interactive, and cohesive). First the "Score" variable was created, in which the total social presence (or total social presence within the category) was summed across all students in one assignment and divided by the number of questions in the assignment. This metric is useful to compare across CKs within a group, but not between groups as group size is not accounted for in this metric. Second, the "Adjusted Score" variable was created, which is

the total social presence (or total social presence within the category) summed across all students in one assignment and divided by the number of questions in the assignment multiplied by the number of students in the group. This metric allows comparison across CKs *and* groups.

In addition to social presence, variables about student performance were collected. This study had three different variables on overall student performance available:

1. Statistical Reasoning and Literacy Instrument (REALI) score (out of 100). This is an assessment that simultaneously measures students' statistical reasoning skills and statistical literacy (Sabbag et al., 2018). This assessment was given to students as part of their final exam.

2. Final exam score (out of 100). This was a cumulative exam given to students at the end of the 10 week long quarter, and

3. Final course grade (out of 100). This is the final, unrounded course grade for students. This grade encompasses all work done through the quarter, including the CKs and final exam scores. This was recorded as both numeric and letter grade ("A", "B", or "C").

To determine which measure was best, distributions of and relationships between performance measures, and course content covered in performance measures were taken into consideration. Ultimately, this analysis will focus solely on the final course grade as the performance metric as it was the best performance measure to differentiate between low and high performing students. This was decided as course grade takes into account more of the work done by students and is more robust to students' day-to-day variability

in performance (i.e., students can perform worse than expected on the final exam and still receive a course grade that reflects their overall performance.) Basically, final course grades give a more complete picture of student achievement than exams. Final course grade data was available for all students and required no additional cleaning outside of merging into the dataset.

3.3.3: Descriptive Associations

As part of the initial exploration of this dataset, associations between the various social presence indicators, final course grades, and groups were investigated. Correlations were calculated and scatterplots were used to display relationships between quantitative variables. Group differences were investigated by creating plots showing the distribution of the variables of interest for each group. Additionally, the adjusted scores were used to detect differences in social presence between groups.

3.3.4 Inferences

To formally examine possible relationships between social presence indicators and performance and answer relevant research questions, linear models were utilized. For these models, ordinary least squares was chosen as the method of regression. Ordinary least squares (OLS) regression is a regression method that models the relationship between a dependent variable and one or more independent variables by finding the line that minimizes the sum of the squared differences between the observed and predicted values. The regression equation for OLS with *n* predictors is as follows:

$$Y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots \beta_n x_{ni} + \varepsilon_i$$

Where *Y* is the response variable, x's are the predictors, and βs are model coefficients.

OLS is valid only when specific data assumptions are met: the relationship between model terms is linear, errors have constant variance (homoscedasticity), and ideally, errors are normally distributed for reliable inference, especially with small samples. Violating these assumptions can bias estimates, reduce prediction efficiency, and lead to incorrect conclusions.

In this analysis, it will be vital to be mindful of the independence of the data. The nature of this data includes clusters (student groups) that could explain some variability between students. If independence is violated, the coefficient estimates will not be impacted, but the standard errors of the coefficients could be underestimated, which could lead to inflated test statistics and significance. Since this research is exploratory, this is something to be mindful of when generalizing results, but not something that will render this analysis useless.

To ensure these assumptions are met, model checking is done. To ensure linearity and constant variance, residuals are plotted against predicted values and examined for curves and fanning patterns. To investigate possible multicollinearity among predictors, variance inflation factors (VIFs) are calculated. A common guideline is that a VIF of below 10 is considered acceptable, though lower VIFs still signify some multicollinearity (Hocking 2003a). To investigate normality, quantile-quantile (QQ) plots are made, and the Shapiro-Wilk normality test is performed. This tests the null hypothesis of normality, therefore a small p-value represents evidence of non-normality. In addition to these assumption checks, Cook's distance is calculated for all points in the model to determine whether a point is influential. In general, if a data point has a Cook's distance of 1 or lower, it is considered to be non-influential (Hocking, 2003b).

Inferential models were fit to explore a few relationships of interest relating to student performance. Thus, the response variable of interest for all models fit was students' performance as measured by their final course grade.

The first potential relationship this analysis addresses is between social presence and performance. To do this, a model with final course grade as a response and total cohesive, total affective, and total interactive social presences as predictors was fit with the following equation:

$$Y_i = \beta_0 + \beta_a x_{ai} + \beta_c x_{ci} + \beta_n x_{ni} + \varepsilon_i$$

where Y is final course grade, x_{ai} is total affective social presence, x_{ci} is total cohesive social presence, x_{ni} is total interactive social presence, and the βs are corresponding coefficients.

The next analysis aims to address the potential relationship between total number of posts and final course grade. To investigate, a model with final course grade as the response and total number of posts was fit, with the following equation:

$$Y_i = \beta_0 + \beta_p x_{pi} + \varepsilon_i$$

where Y is final course grade, x_{pi} is the total number of posts, and the βs are corresponding coefficients.

Next, it is of interest to determine whether the total posts variable is explaining variation beyond what is explained by social presence. To do this, total posts and all three social presence category totals were included in a model, with the equation below:

$$Y_i = \beta_0 + \beta_a x_{ai} + \beta_c x_{ci} + \beta_n x_{ni} + \beta_p x_{pi} + \varepsilon_i$$

where Y, x_{ai}, x_{ci}, and x_{ni} are the same as previously described, x_{pi} is the total number of posts and the βs are corresponding coefficients. However, this model is anticipated to

have multicollinearity issues due to total social presence and total posts being related. To ensure this will not be an issue, this model will also be fit with proportions of social presence categories (total number of social presence instances in each category, divided by the total instances of social presence). One category (interactive) will be removed to avoid singularity, since the three proportions will add up to one for each student. The model equation will look similar:

$$Y_i = \beta_0 + \beta_{pa}x_{pai} + \beta_{pc}x_{pci} + \beta_p x_{pi} + \varepsilon_i$$

Where Y is still final course grade and x_p is still the total number of posts, but x_{pa} and x_{pc} are the *proportions* of affective and cohesive social presences accordingly.

Lastly, this study aimed to explore the relationships between specific social presence indicators identified during the coding process. Self-disclosure and agreement emerged as variables of interest based on anecdotal observations made during the coding process. To address variations in student post counts and potential multicollinearity, proportions of these indicators (total number of instances of self-disclosure and agreement, accordingly, divided the total instances of social presence) were used in the analysis, leading to the following model equation:

$$Y_i = \beta_0 + \beta_{ag}x_{agi} + \beta_{dis}x_{disi} + \varepsilon_i$$

where Y is final course grade, x_{agi} is the proportion of agreement, x_{disi} is the proportion of self-disclosure, and the βs are corresponding model coefficients.

Chapter 4

RESULTS

4.1 Distributions

To examine students' overall participation in the CK assignments, the total number of posts for each student throughout the quarter was examined. In Figure 4, the distribution of total posts by student has a large spike around 76 total posts. This was not unexpected as there were 76 total questions in all CK assignments throughout the quarter, which students were required to have at least one response to. Each dot represents one student. Many students (14 out of 31) fall above the spike, suggesting they interacted more than required. There is one low and a few high extreme values in the distribution. The highest student outlier is a standout student who was consistently an outlier in multiple observed variables and will be noted in the following distributions as the "standout student" and colored in red in the figures. The second highest student outlier is a student in the same group as the standout student.

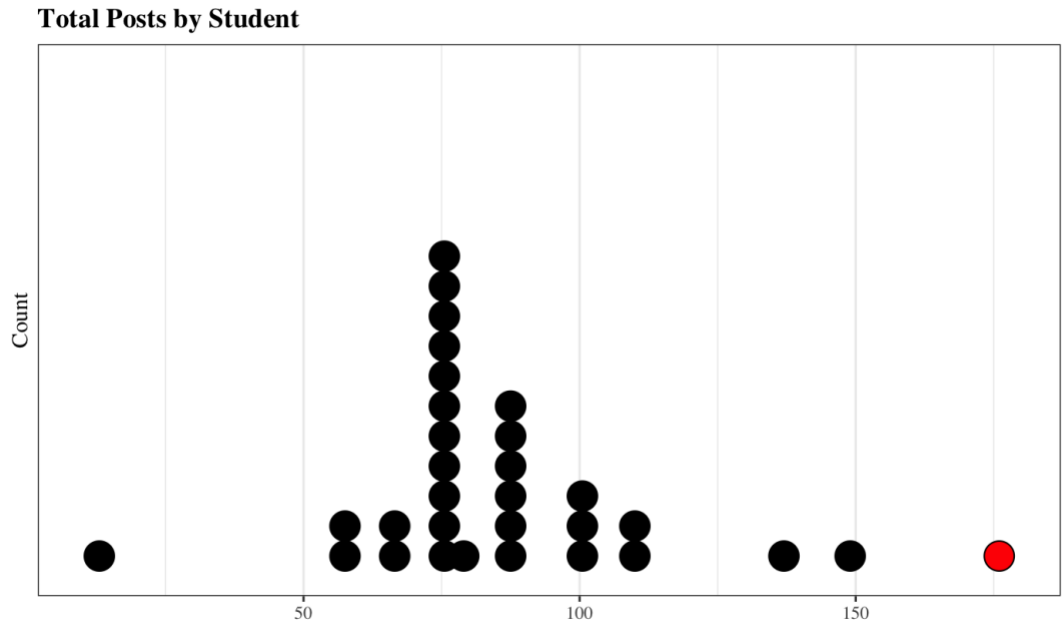


Figure 4: Total posts over quarter by student

To examine students' display of social presence in the CK assignments, the distribution of total number of social presence instances per student throughout the quarter was obtained for all indicators of social presence together (Figure 5), for each of the 11 indicators separately (Figure 6), and for each of the three primary categories of social presence (Figure 7).

Figure 5 displays the distribution of the total number of instances that a student displayed any sort of social presence over all CK assignments administered throughout the quarter. A somewhat symmetric distribution with a few high outliers to the right is displayed. The highest student outlier was the standout student.

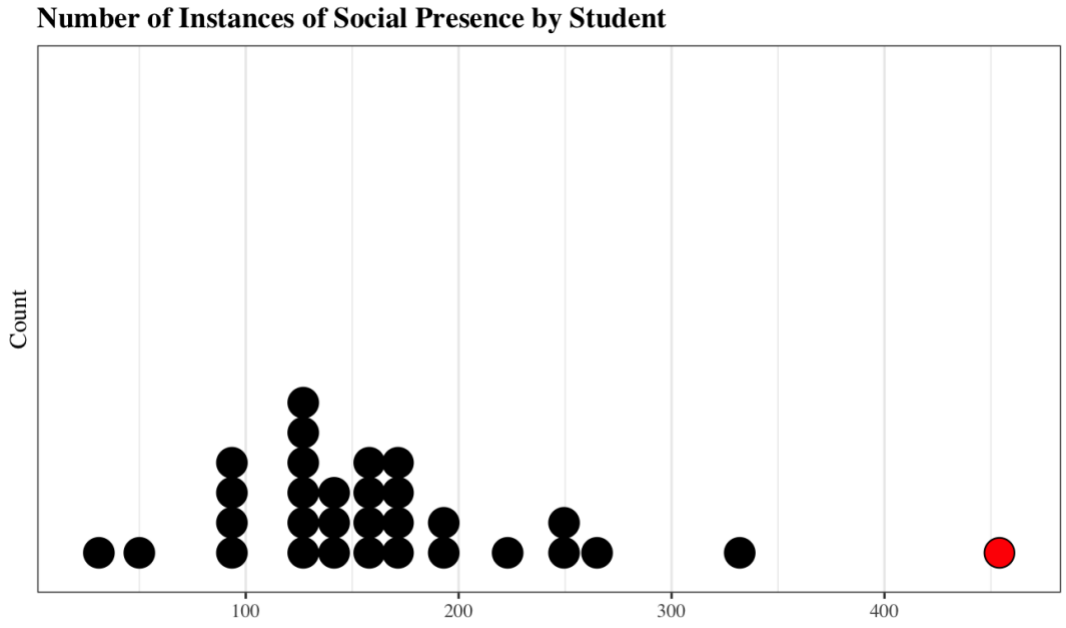


Figure 5: Total instances of overall social presence by student

The distribution of the total number of instances that a student displayed for each of the 11 categories of social presence over all CK assignments administered throughout the quarter is displayed in Figure 6. The Quoting and Humor social presence indicators were excluded due to their minimal use and variability. Many social presence indicators have right-skewed distributions with most values close to 0 (emotion, asking and answering question, appreciation, and phatics). The other social presence indicators (agreement, pronouns, self-disclosure, and vocatives) are the most commonly used social presence indicators. These four indicators have a wider, flatter spread.

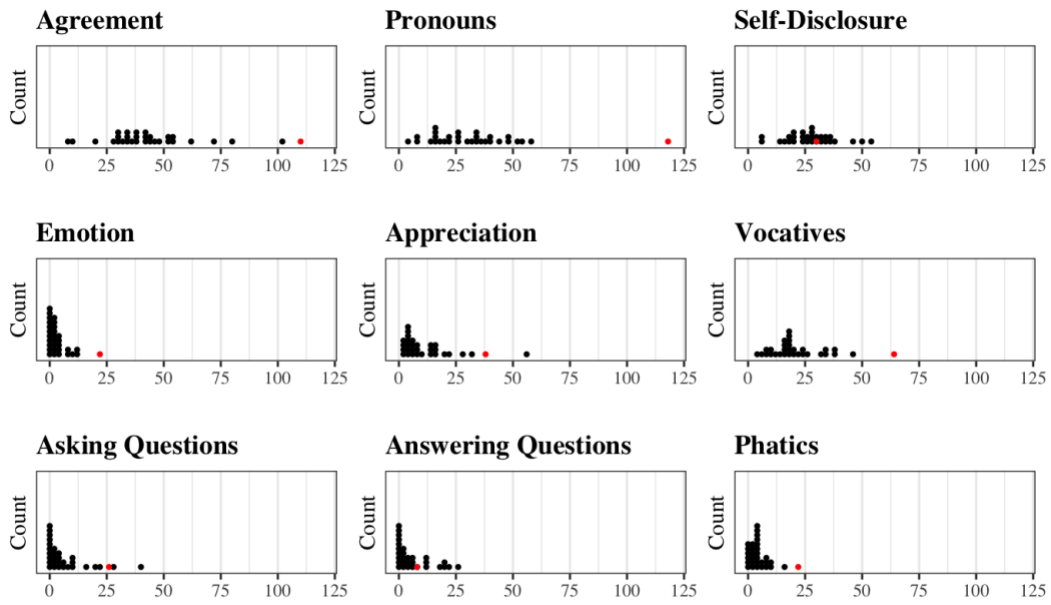


Figure 6: Total instances of social presence by student for each of 9 social presence indicators

The following plot also shows the distribution of total social presence instances by student but now focusing on each of the three big categories of social presence (cohesive, interactive, and affective). The distribution of the total instances of displays of *cohesive* indicators of social presence, seen in Figure 7, is bimodal with peaks around 45 and 75, and concentrated between 0 and 100 instances per student, with an extreme outlier to the right. This outlier is once again the standout student observed earlier. The distribution of the total instances of display of *interactive* social presence indicators (Figure 7) is fairly flat with two notable outliers, the standout student and another student from the same group. Lastly, the distribution of *affective* social presence indicators by student stands out from the other social presence distributions. It does not have extreme values on both sides of the distribution which makes it the most symmetric compared to the other two. It is also important to note that the range of values for this variable is much smaller than the

previous two, with a median of 33 instances compared to medians of about 60 for both interactive and cohesive presences.

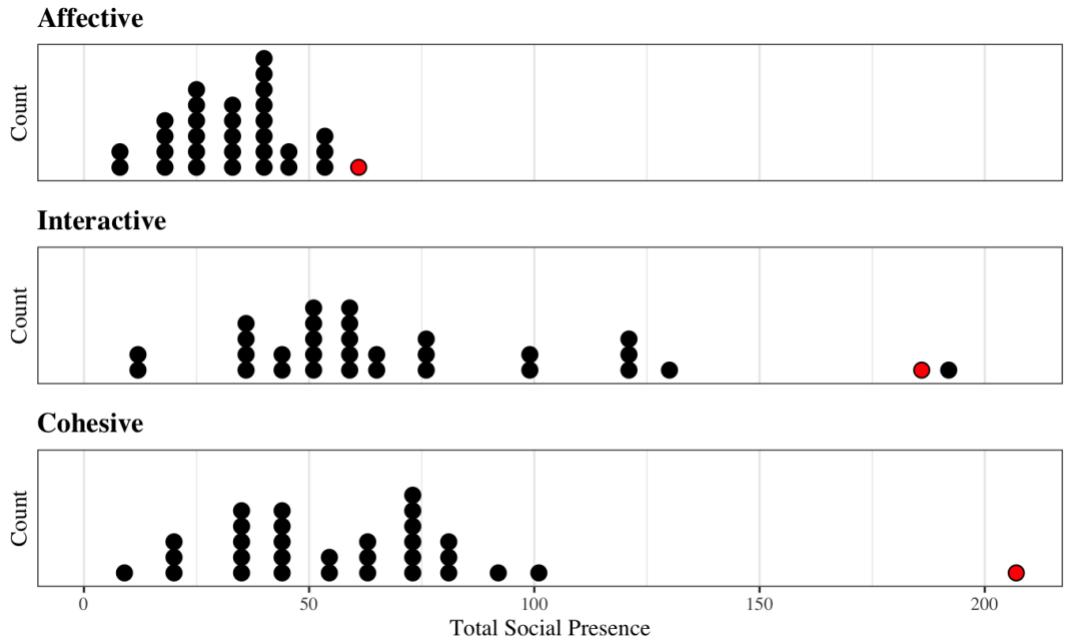


Figure 7: Total instances of cohesive, interactive, and affective social presence by student

Similar to Figure 7, Figure 8 shows the density plots of all three categories of social presence overlaid on one plot. The cohesive and interactive categories have a similar center (medians are 57 and 61 instances respectively), but the *interactive* category is more right-skewed and has a heavier tail. The *affective* category stands out again, with a more condensed distribution, with no students exceeding 75 instances of *affective* presence across the quarter. In fact, the maximum of the *affective* category is 61 instances, which is about the same as the medians for the other two categories. The *affective* and *cohesive* categories have the same number of indicators that fall into the category (three each), while the *interactive* category has five indicators. This potentially

explains differences between the *interactive* category and the *affective* category, but not between the *affective* and *cohesive* categories.

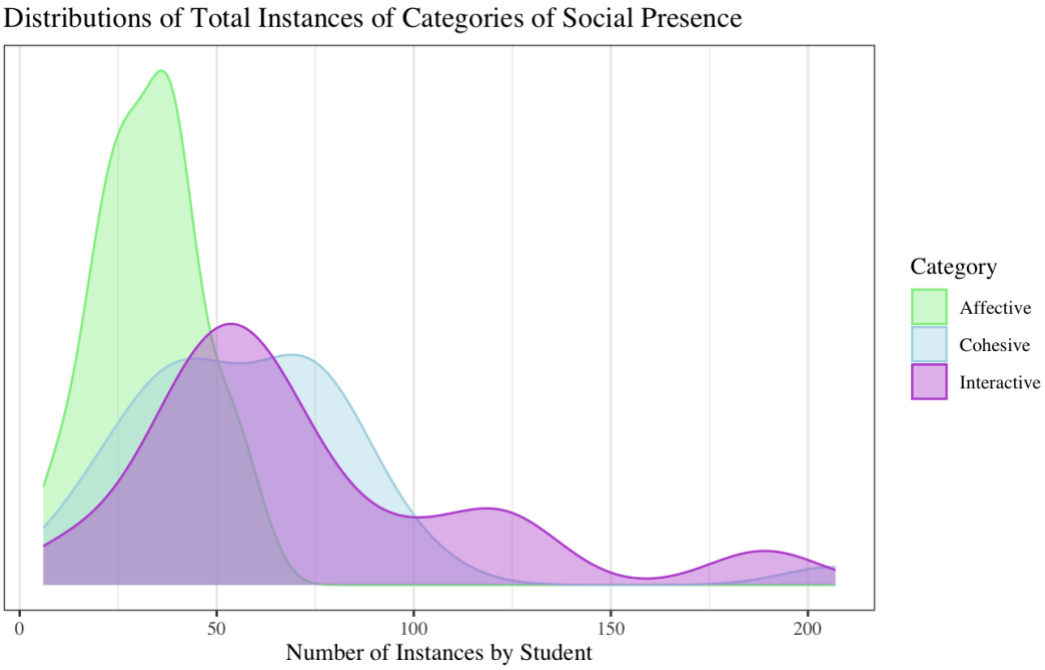


Figure 8: Density Plots of SP Categories

Table 6 illustrates the overall percentage of instances that each of the three categories of social presence were displayed by the students. Notably, the *affective* category demonstrated the lowest relative frequency of instances. The *cohesive* category exhibited the highest prevalence of social presence across all students. For a more comprehensive analysis, the distributions of the 11 indicators across all students are presented in Table 7.

Table 6: Distribution of SP categories across all students

SP Category	Percentage Observed Across All Posts
Affective	19.94%
Cohesive	43.78%
Interactive	36.28%
Total	100%

Table 7 is sorted by descending popularity. Each of the three categories of social presence has an indicator that monopolizes the category; agreement for interactive, pronouns for cohesive and self-disclosure for affective. These three indicators make up the majority of their respective categories and seem to be the driving force behind the categories' popularity. This is especially notable with the affective category, with self-disclosure accounting for 17% of all social presence instances and the remaining two indicators in the category, emotion and humor, only accounting for 2.5% and 0.4% of all instances of social presence respectively. It is also necessary to note that the vocative indicator, part of the cohesive category, accounts for 13% of all instances of social presence. Therefore, cohesive has two out of three of its indicators each accounting for over 10% of all instances of social presence. These popular categories demonstrate why the cohesive and affective categories' distributions differed so much despite the same number of indicators belonging to each category.

Table 7: Distribution of SP indicators across all students

SP Indicator	SP Category	Percentage Observed Across All Posts
Agreement	Interactive	27.29%
Pronouns	Cohesive	19.8%
Self-Disclosure	Affective	17.06%
Vocatives	Cohesive	13.31%
Appreciation	Interactive	7.7%
Asking Questions	Interactive	4.69%
Answering Questions	Interactive	4.05%
Phatics	Cohesive	3.17%
Emotion	Affective	2.46%
Humor	Affective	0.41%
Quoting	Interactive	0.06%
Total		100%

To gain deeper insight regarding the use of specific social presence indicators, the most displayed social presence indicator was determined for each student. Of all eleven categories, only four ever occurred as a student's "favorite" (most commonly observed across all assignments); agreement, self-disclosure, pronouns, and vocatives (Figure 9). These four indicators are identical to the top four indicators across all students overall. Agreement was the most common top social presence indicator, with 19 out of 31 students showing agreement the most. The least common top social presence indicator was the use of vocatives, with only one student using vocatives more than any other indicator.

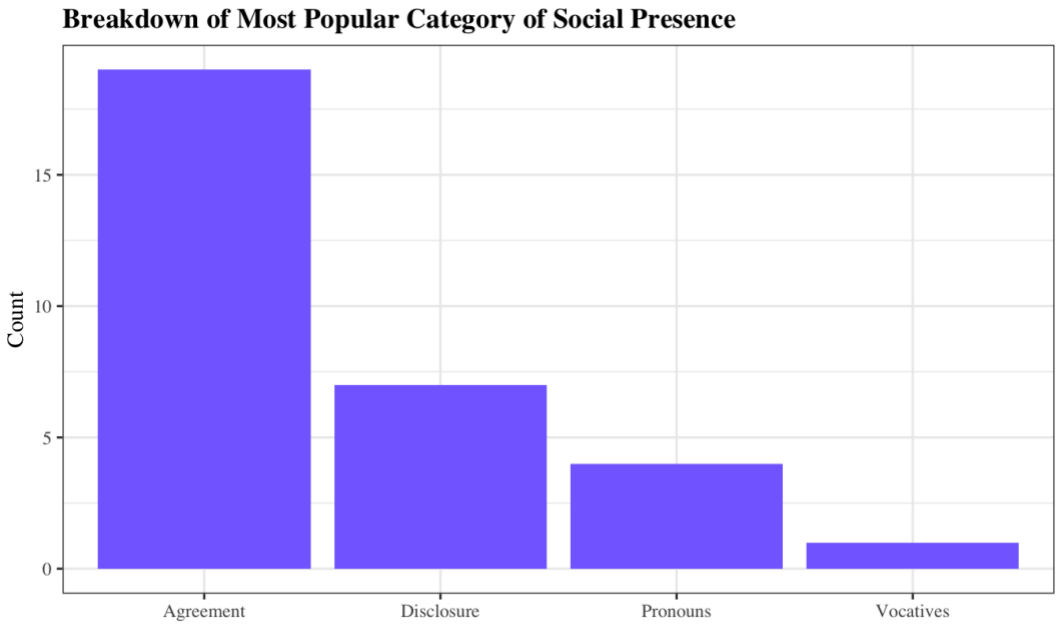


Figure 9: Bar chart showing distribution of most popular indicators

Figure 10 displays the distribution of final grades. Six students in the sample earned an A grade in the class, nine students earned a B, and sixteen students earned a C. The mean final course grade was 81.9%, the median was 79.91%. The highest grade in the sample was 96.5%, belonging to the standout student, and the lowest grade in the sample was 70.65%.

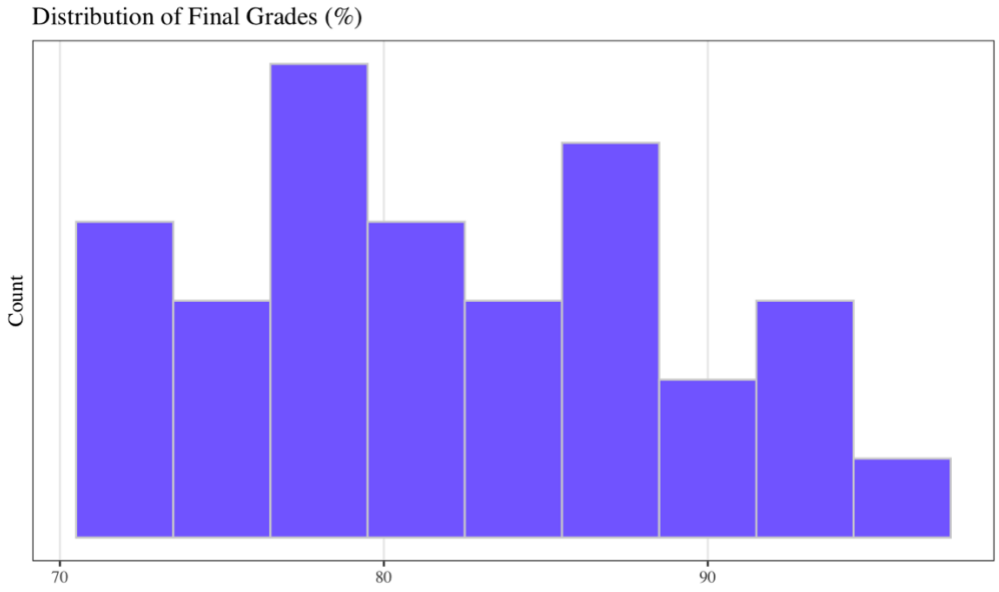


Figure 10: Distribution of final grades

4.2 Descriptive Associations

The previous section reported distributions for the total number of social presence instances by student and the total number of posts for each student throughout the quarter. Figure 11 displays the association between these two variables. As total posts increase, total social presence instances also tend to increase, indicating a positive association between these variables. They are also highly correlated (correlation coefficient of 0.92).

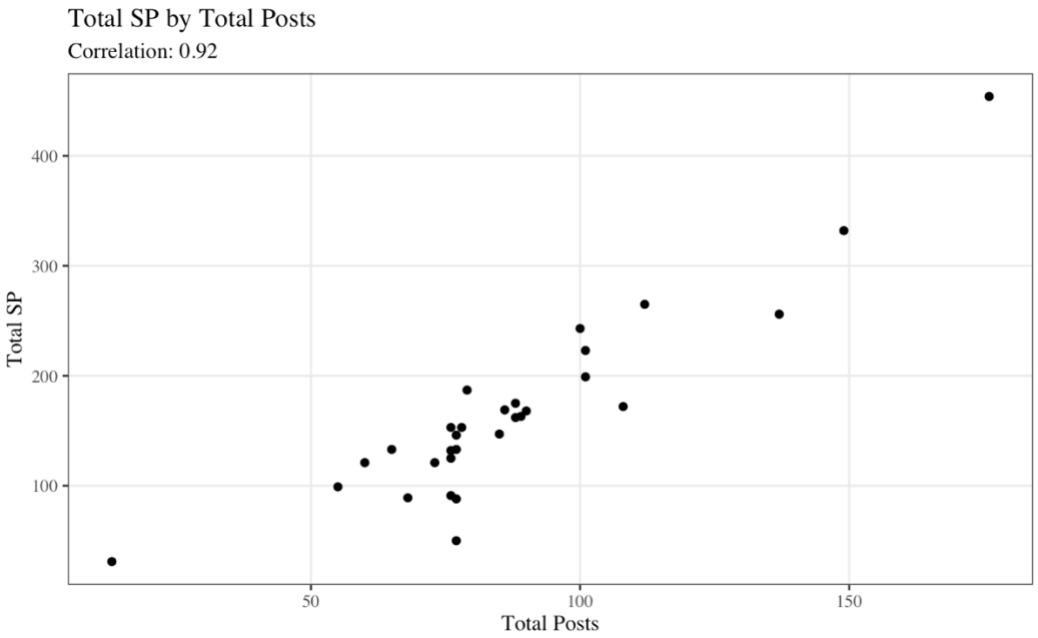


Figure 11: Relationship between total SP and total posts

Following the analysis of individual student-level variable distributions, variables were aggregated according to student groups. Variables were examined at the group level and subsequently compared with student performance in order to identify relationships. After relationships were identified, linear models were built to test these relationships.

4.2.1 Group Level

Continuing the discussion surrounding students' use of social presence indicators, Figure 12 displays proportions of students' use of each of the 11 social presences by group. Each student is represented by a single bar and organized in their groups (1, 4, 6, 7, 9, 11, 14, 15, and 17). Figure 13 displays this information at the group level, with each bar representing a group (1, 4, 6, 7, 9, 11, 14, 15, and 17).

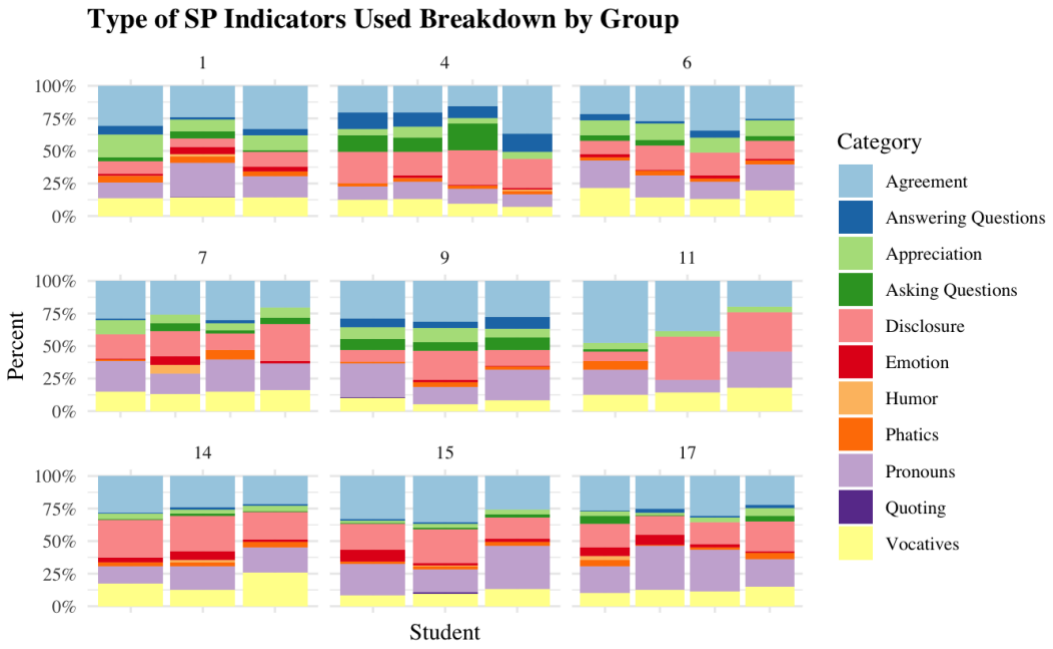


Figure 12: Breakdown of social presence indicators used by student and group

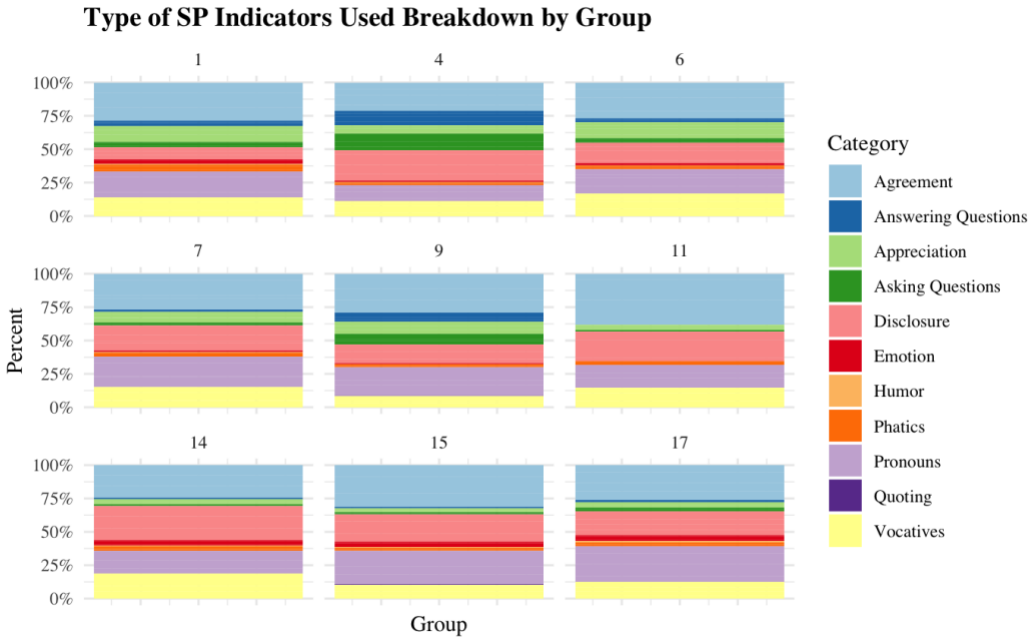


Figure 13: Breakdown of social presence indicators used by group

The distribution of the proportions of social presence indicators seems to differ across groups, with groups 4 and 9 showing a higher proportion of students asking and answering questions compared to other groups. Some groups demonstrate use of more indicators than others, for example groups 1 and 17 show a larger variety of types of social presence indicators, while group 11 shows minimal use of social presence indicators. All groups seem to display a large proportion of their social presence instances falling into the agreement and self-disclosure categories. Distinct variability exists among groups in the application of social presence indicators, with certain students demonstrating as few as five of the 11 indicators throughout the quarter. Students within the same group tend to have a similar proportion of social presence indicators and tend to utilize the same categories of social presence (cohesive, interactive, and affective). Group seems to explain some type of variability in student distribution of social presence indicators. To further illustrate this relationship, two additional graphs depicting the proportion of the three categories of social presence (cohesive, interactive, and affective) were developed (Figures 14 & 15).

Figure 14: Breakdown of indicator categories used by group

Figure 15: Breakdown of indicator categories used by student and group

Figure 15 shows the proportion of each category of social presence across groups and students. Most groups have the largest proportion of interactive social presence, followed by cohesive social presence. Many groups have a nearly equal proportion of these two categories. It is clear that students tend to have similar social tendencies to their group members except for group 11 which seems to have a student displaying less interactive social presence indicators compared to their group members. Affective is never the top category for a group, though groups seem to display categories of social presence at different rates with groups 14, 15, and 17 showing possibly a smaller proportion of interactive social presence compared to the other groups (Figure 14).

4.2.2 Group Display Through CKs

To develop a further understanding of group differences and how they could change throughout the quarter, social presence adjusted scores were investigated for overall social presence and for each of its three categories (cohesive, interactive, and affective).

As described in section 3.3.2, the adjusted social presence score measures social presence in a single CK by number of students and questions, this way this score can be compared across both assignments and student groups. Figure 16 displays smoothers of the score over time, with each group represented by one line. It is clear that Group 1 stands out from the others. This is the group that the previously noted standout student belongs to. Group 6 seems to have a steep increase in adjusted score compared to other groups after CK 5.2 (week 6). Similar graphs were created for all three categories of social presence (Figures 17 - 19)

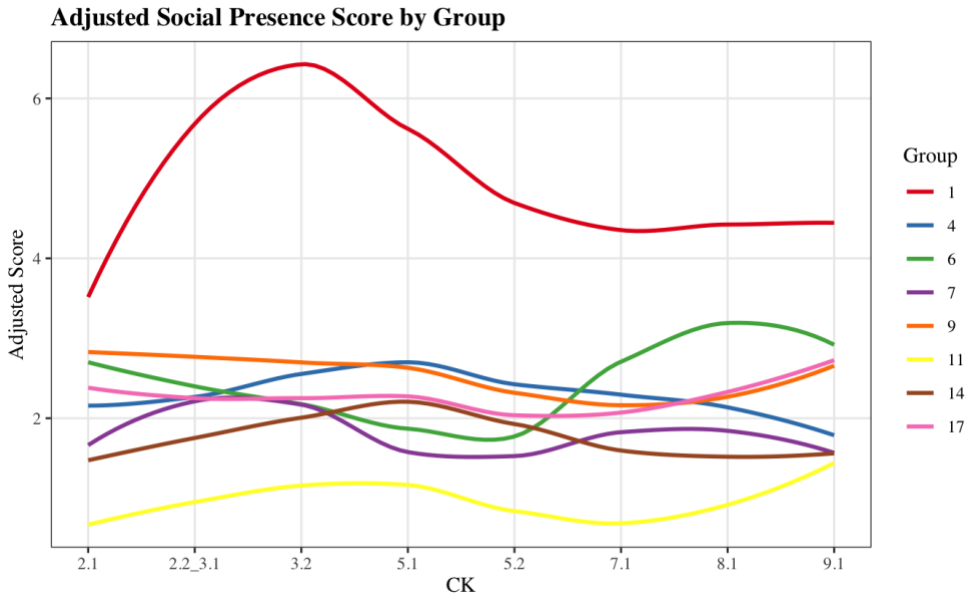


Figure 16: Adjusted SP score for assignments by group

Figures 17, 18, and 19 display adjusted scores overtime for the cohesive, interactive, and affective categories. Both cohesive and interactive plots look similar to overall social presence with the same standout group, remaining groups seeming to follow a similar ranking, and no clear pattern that groups are following. After CK 5.2 (week 6), four groups show an increase in the cohesive category of social presence (Groups 6, 9, 11, and 17). There is a similar pattern in both the interactive category and overall social presence, but on a smaller scale. On the other hand, the distribution of affective scores is distinct from the cohesive and interactive scores. Most groups display a strong and consistent pattern of affective scores dipping mid-quarter (CKs 5.1 and 5.2, week 6), though the dips in groups 4 and 17 are lesser than the others. While group one remains as the group with the highest scores for the majority of the quarter, it is not a clear standout as it was in the overall, cohesive, and interactive scores.

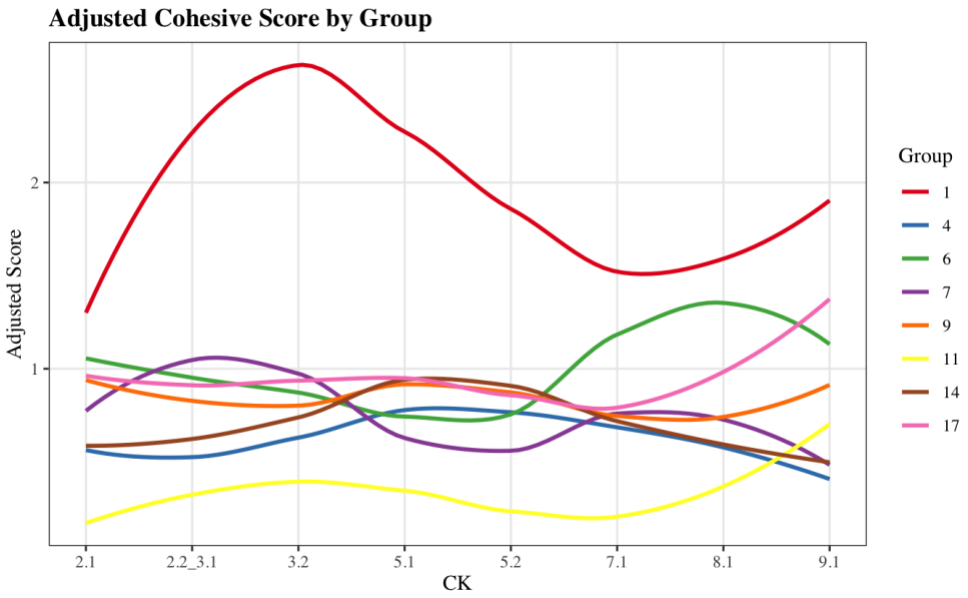


Figure 17: Adjusted cohesive SP score for assignments by group

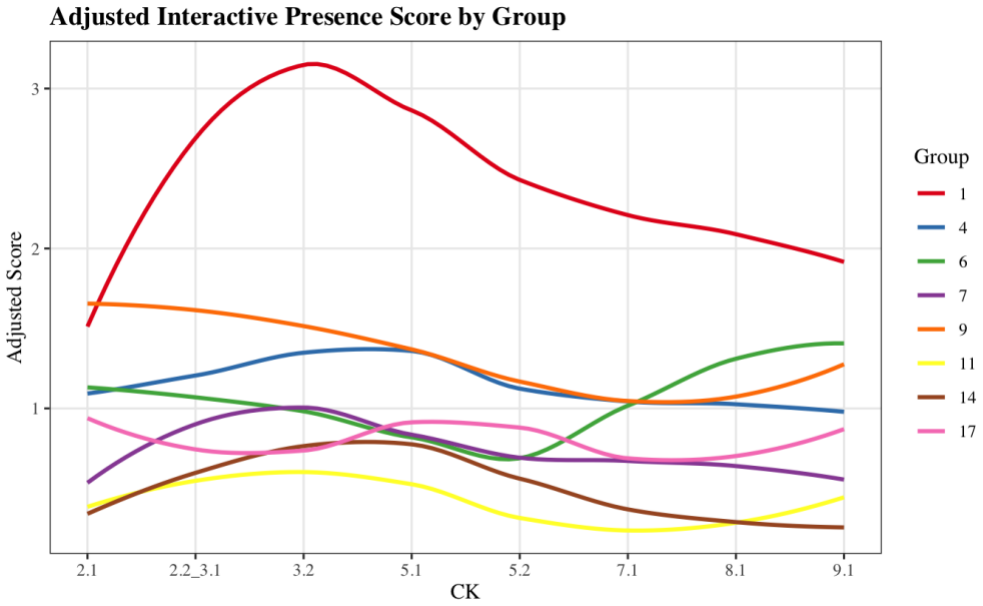


Figure 18: Adjusted interactive SP score for assignments by group

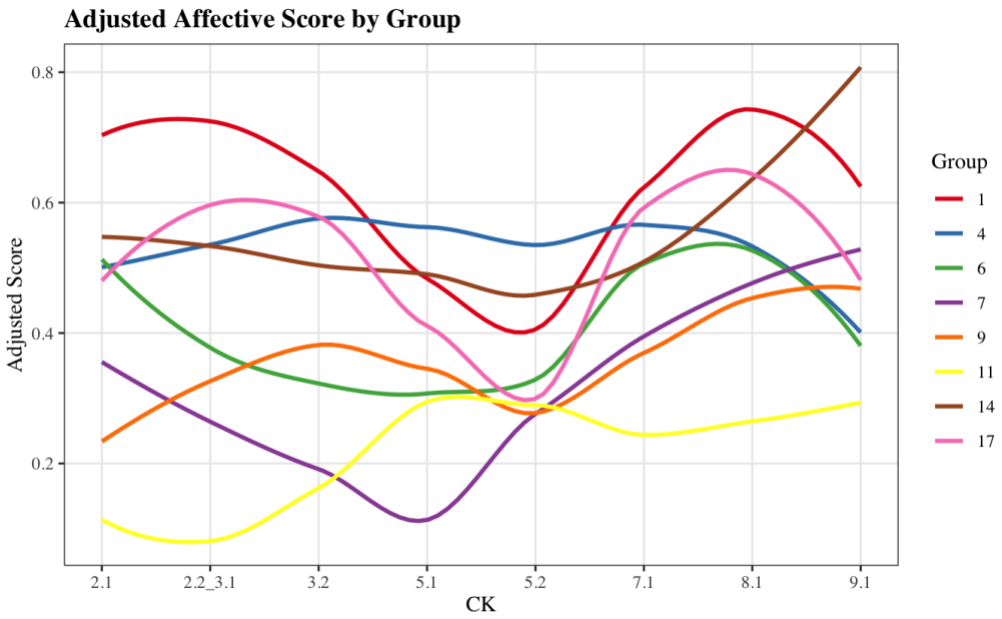


Figure 19: Adjusted affective SP score for assignments by group

4.2.3 Performance

To investigate student's performance and possible associations with social presence, final course letter grades and percentages (out of 100) were utilized. Firstly, letter grades were used to demonstrate differences between higher performing and lower performing students and how they could relate to total number of posts and total instances of social presence display.

Figure 20 displays the distribution of total posts per student by letter grade earned. Notably, median total posts seem to increase as grade increases. The median number of total posts throughout the quarter for A, B, and C students are, 98, 86, and 77 respectively. Students in the A grade category have a larger variability in the total number of posts throughout the quarter (IQR of 53) than the students in the B and C categories (IQRs of 24 and 6.75 respectively), with C having a noticeably smaller

variability. This can partially be explained by the size of each of these groupings (A had 6 students, B had 9 students and C had 16 students). Additionally, the A group contains the standout student, who causes a bit of a right skew in this group. This plot suggests that higher performing students may have more responses in the discussion section of the CKs through the quarter than lower performing students.

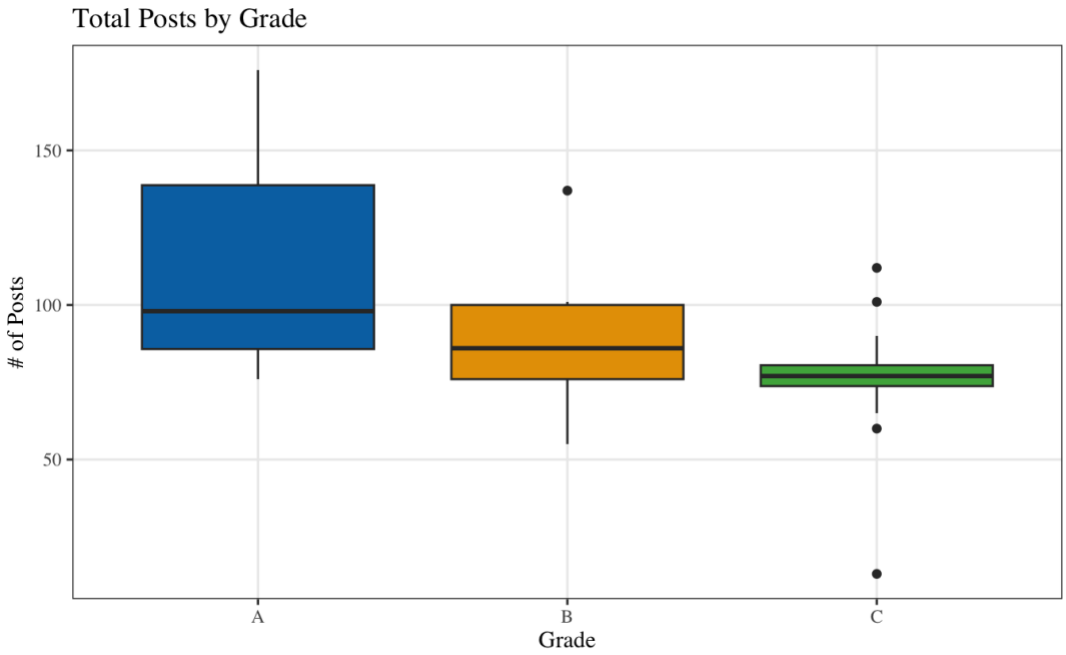


Figure 20: Boxplot of total posts by letter grade

The relationship between letter grade and total social presence (Figure 21) is similar to the relationship between letter grade and total posts. However, students who earn As and Bs have similar median total posts throughout the quarter. The median total social presence for grades A, B, and C are 173.5, 169, and 134.5, respectively. This still suggests that students who score higher grades may have more instances of social presence displayed than those who score lower grades. These similarities between the relationships are expected due to the strong correlation between total posts and total

social presence (see Figure 11). Additionally, the pattern of variability (A highest with an IQR of 140, B middle with an IQR of 98 and C lowest with an IQR of 41.8) is similar to the pattern of variability across number of posts, though less exaggerated

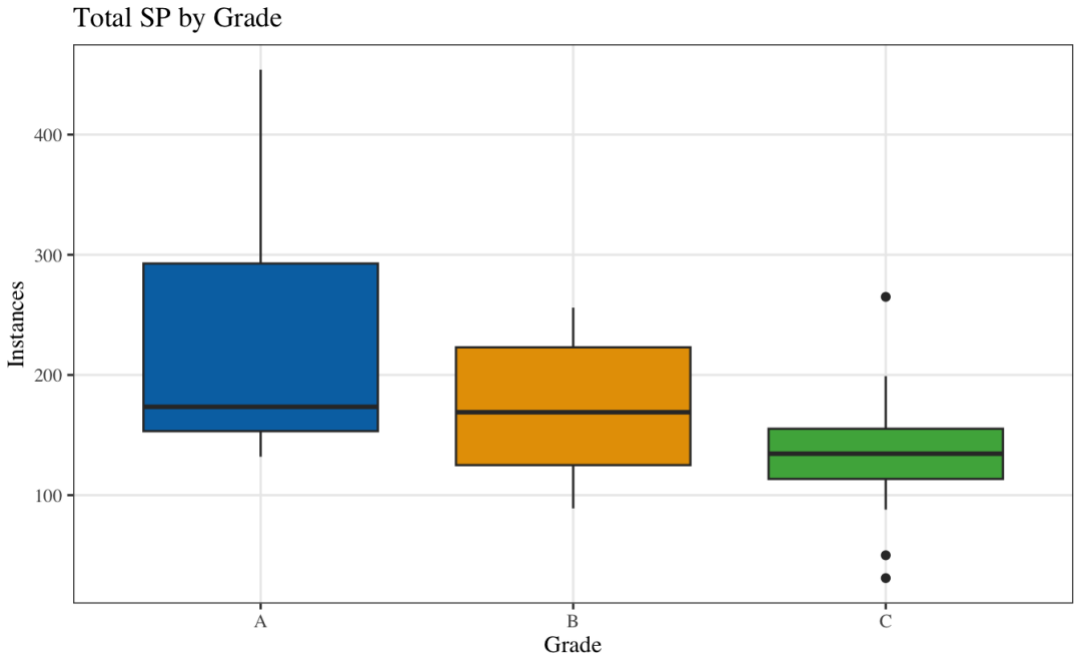


Figure 21: Boxplot of total SP by letter grade

The means for student totals in the A category tend to be larger than the medians. This is due to the standout student having many more posts and instances of social presence than the rest of the group, in addition to the small group size.

To further investigate possible differences in groups' performance and social presence displayed throughout the quarter, CK assignment was taken into consideration.

Figure 22 displays total social presence instances per question in each CK for students by letter grade. This is calculated by summing up the total social presence instances a student displayed in one assignment, then dividing by the number of questions in the

assignment. This adjustment is done to allow for comparisons between assignments with differing numbers of questions. Each smoother represents all students in the grade group, calculated using the Loess method. This figure indicates a consistent trend throughout the quarter: students with higher grades had a greater (adjusted) frequency of social presence display. Specifically, throughout the quarter, the total number of social presence instances was consistently highest for A students, followed by B students, and then C students. This reinforces the idea that higher academic achievement is possibly associated with more frequent social presence displays, and this seems to be true from beginning to end of the quarter. There is another consistent pattern across A and C performance groups: an increase at the beginning of the quarter up to CK 3.1 (week 3) and a dip in the middle of the quarter (CK 5.2, week 6). Grade B students seem to reach their peak of social presence display a little later in CK 5.2 (week 6) but show a steady decrease in total social presence display after that.

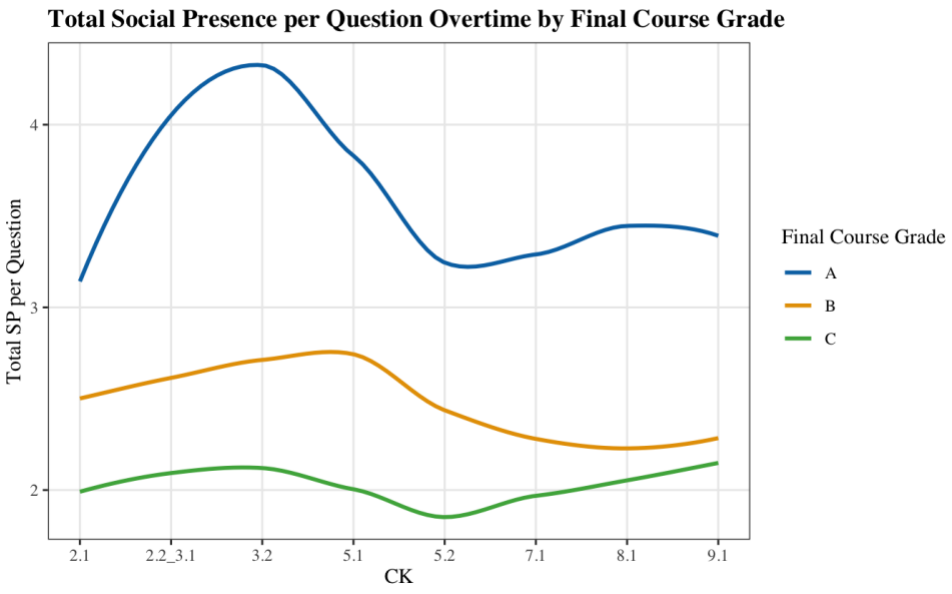


Figure 22: Total social presence per question through the quarter by final grade

To identify potential linear relationships between social presence, performance, and total number of posts, scatterplots were created, and correlations were calculated.

A linear association of moderate strength (correlation of 0.48) was found between course grade and total posts throughout the quarter (Figure 23). The positive association implies that as total posts increased, students' final percentage grade in the class tended to increase as well. Previous grade-level group analysis identified differences; this new analysis builds upon that by demonstrating a possible linear relationship between the variables, rather than simply noting distinctions between the groups. One important aspect of this graph is that there seems to be four students who are affecting the possible association between these variables, with most of the students clustering in the middle of the plot with total number of posts between 50 and 100. The point in the top right corner is the standout student previously discussed.

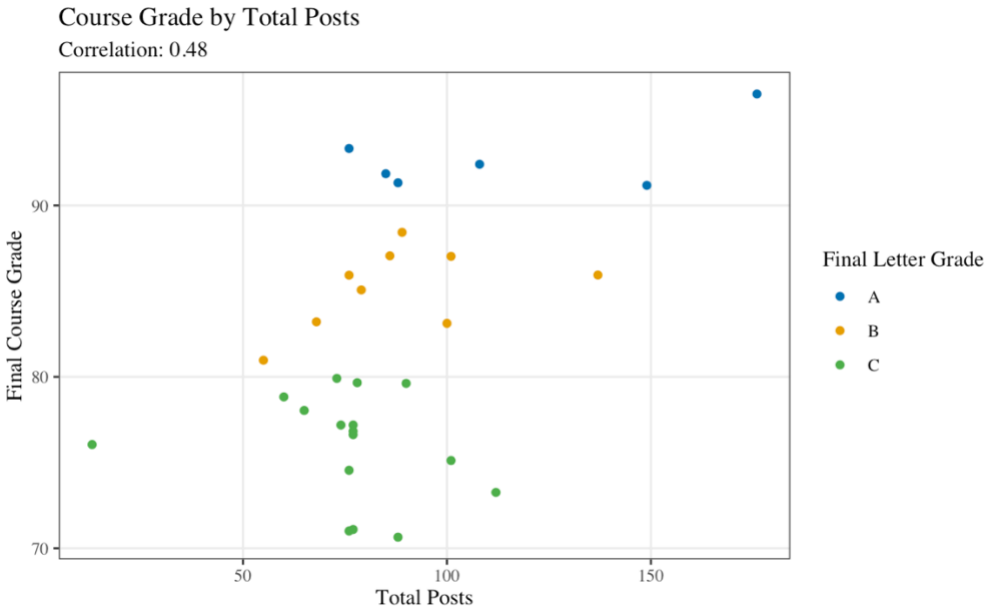


Figure 23: Scatterplot and correlation of course grade by total posts

Similar analyses were done for overall social presence and all three categories of social presence (Figures 24 - 27). Similar results to the previous grade-level group analysis were found; moderate positive relationships with grade for overall social presence and total interactive social presence (correlations 0.47 and 0.38 respectively), no apparent relationship between grade and total affective social presence (correlation of 0.06) and a relatively strong positive relationship between grade and total cohesive social presence (correlation of 0.6).

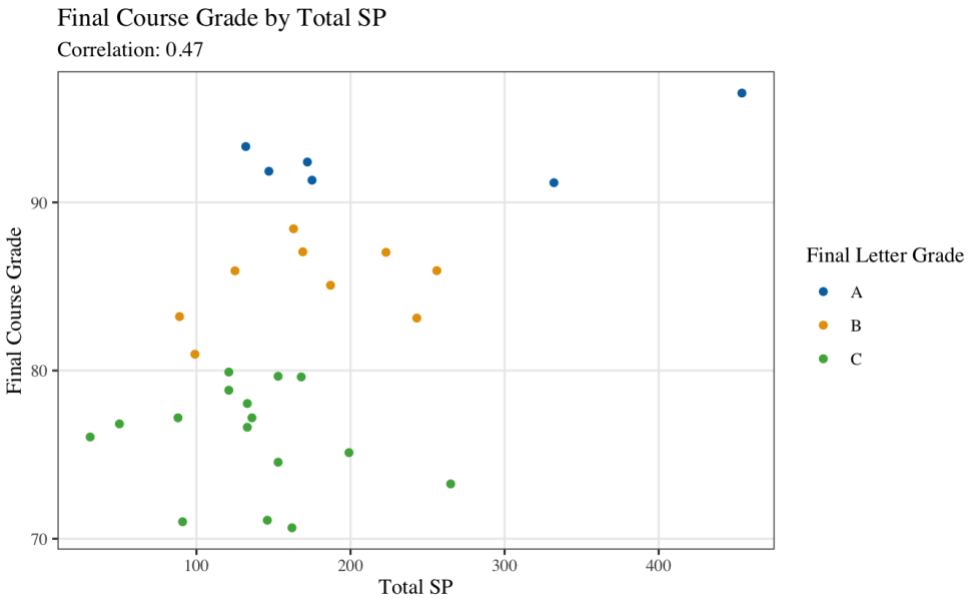


Figure 24: Scatterplot and correlation of course grade by total social presence

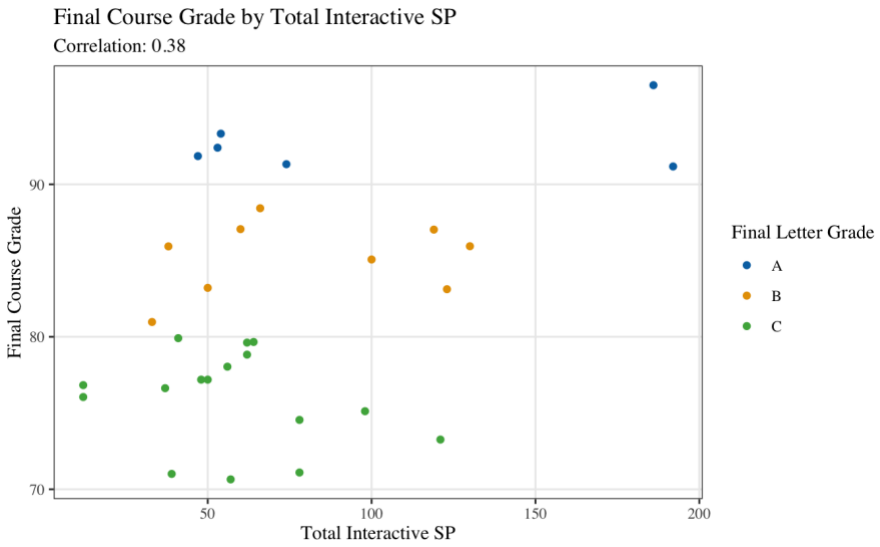


Figure 25: Scatterplot and correlation of course grade by total interactive SP

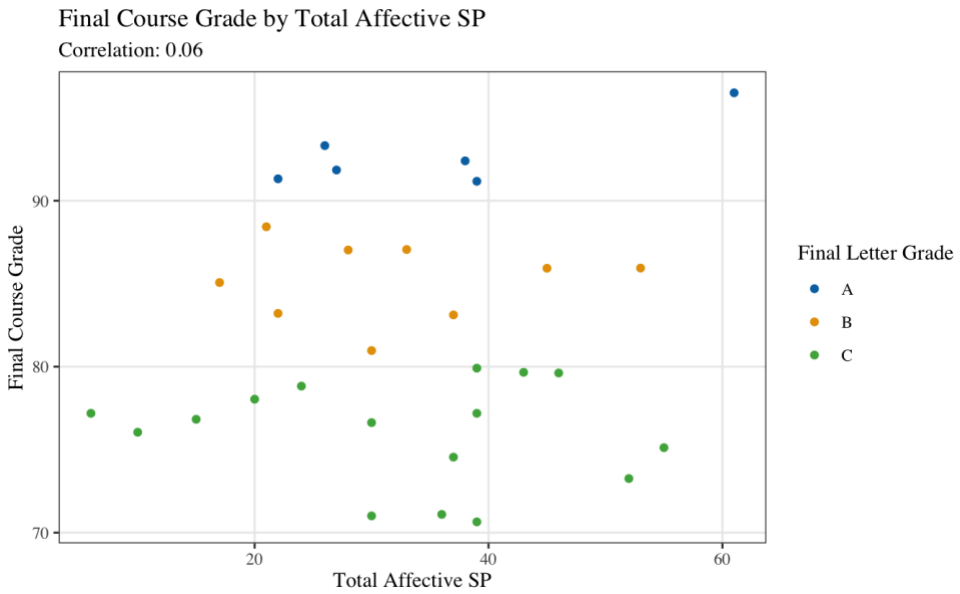


Figure 26: Scatterplot and correlation of course grade by total affective SP

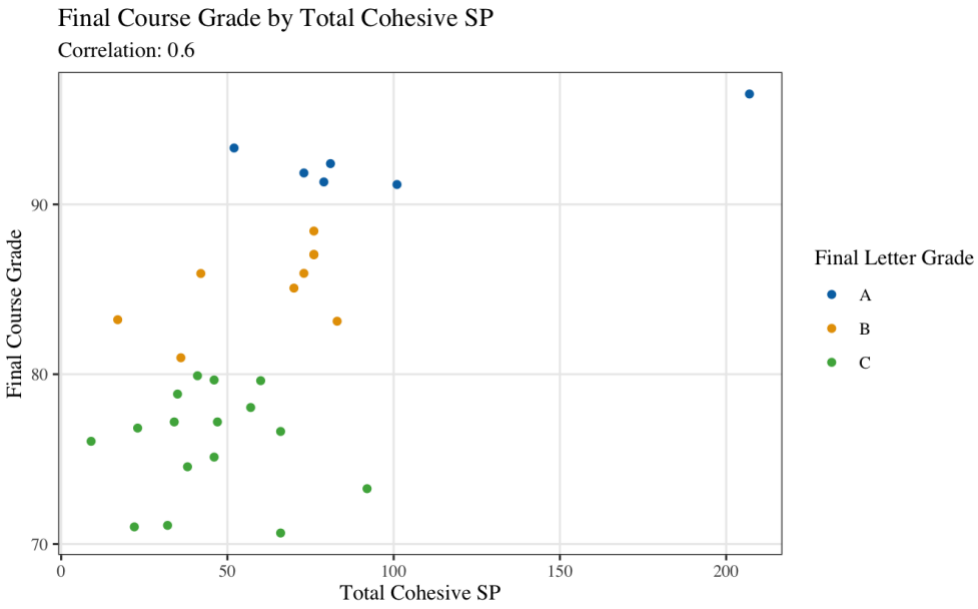


Figure 27: Scatterplot and correlation of course grade by total cohesive SP

To address potential collinearity issues arising from the correlation between overall social presence and total cohesive social presence, as well as between total posts and total cohesive social presence, the proportion of cohesive social presence was analyzed (Figure 28). A moderately positive relationship was still present, and no obvious outliers were observed.

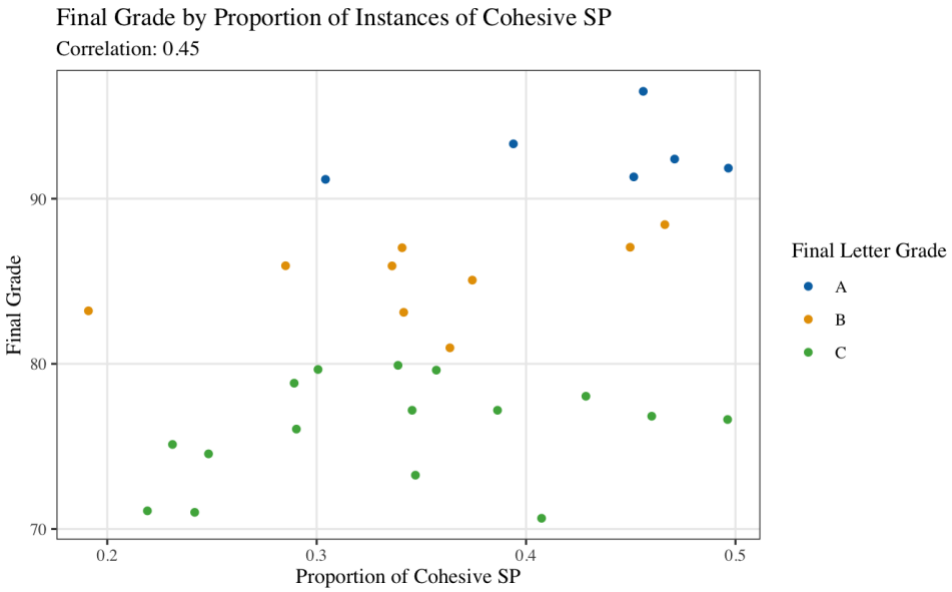


Figure 28: Scatterplot and correlation of course grade by proportion of cohesive SP

Similarly, the proportion of self-disclosure was studied (Figure 29), revealing a relatively strong *negative* linear relationship with final course grade (correlation of -0.57). This suggests that students who display vulnerability at a higher rate tend to have a poorer course performance overall.

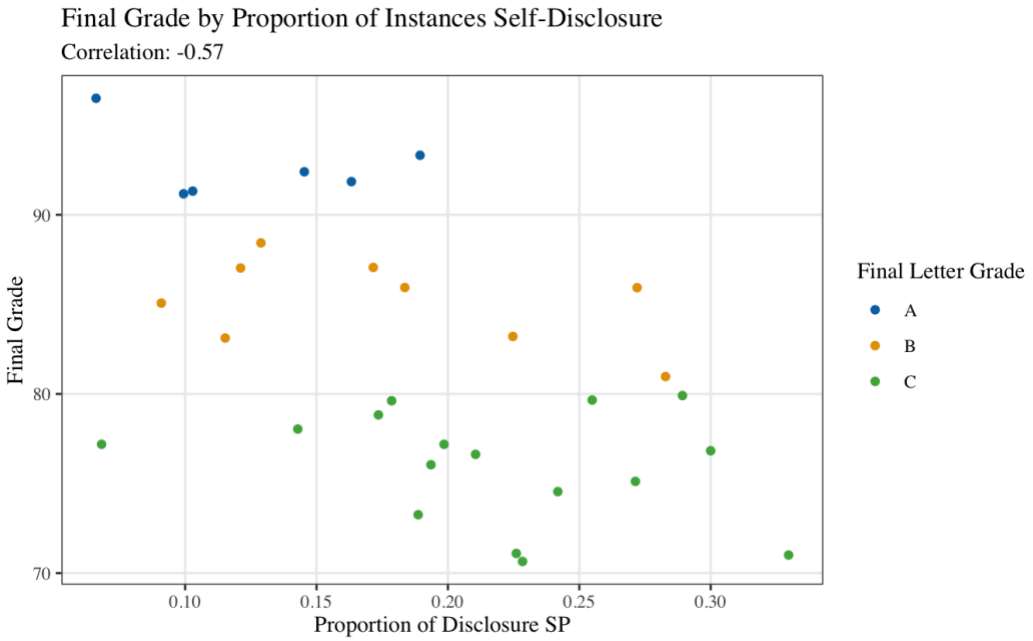


Figure 29: Scatterplot and correlation of course grade by proportion of self-disclosure

These observed relationships were used to inform the model building process.

4.3 Inferences

This section will detail the results of inferential analyses aimed at exploring potential relationships between social presence indicators and academic performance, using linear models. Two main models were developed and tested to identify significant associations and understand the extent to which social presence indicators are associated with students' final course grade. One model investigates social presence and total posts as predictors of final course grade. The other looks at specific indicators (self-disclosure and agreement) and how they may be associated with students' final course grades. These models were carefully evaluated for statistical assumptions and refined to address issues such as multicollinearity.

First, an initial model was fit to investigate the relationship between social presence and performance. In this model, all three totals of categories of social presence (affective, cohesive, interactive) were used as predictors. This model had only one significant predictor - total cohesive social presence. When fit as a sole predictor, total cohesive social presence remained significant and no assumptions were violated, excluding a singular influential point (Cook's distance = 0.51).

Next, a model was fit to investigate the relationship between total posts and performance. In this model, only total posts was included as a predictor and it was found to be significantly associated with final course grade, and all assumptions were not violated.

With significant predictors in both models, it is possible that the total number of posts explains the variation in performance past what social presence does. To investigate this, a model was fit with totals for all three categories of social presence *and* total posts. This model resulted in a high VIF (6.52) for total posts, providing some evidence of multicollinearity. To adjust for this, a model using proportions of affective and cohesive presence (interactive was excluded to avoid singularities) and total posts was fit. This model fit found the proportion of cohesive social presence and total number of posts to be significantly associated with final course grade. All assumptions were tested and not violated.

This resulted in one of the final models: total posts and proportion of cohesive presence as predictors of final course grade. This model will be called Model 1. Again, model assumptions were not violated, and resulted in strong evidence that both total posts and proportion of cohesive presence are associated with final grade.

Table 8: Results of Model 1

Variable	Coefficient Estimate	P-Value
Intercept	61.1400	<0.0001
Total Posts	0.1043	0.0099
Proportion of Cohesive SP	32.7071	0.0161

Model 1 suggests that both total posts and proportion of cohesive social presence have a statistically significant and positive relationship with final course grade. The model estimates that each one post increase in posts made through the quarter is associated with a 0.1043 increase in final course grade percentage points, adjusting for the proportion of cohesive social presence. The model also estimates that each 0.1 (10% points) increase in proportion of social presence is associated with an increase of 3.27 percentage point increase in final course grade, adjusting for total posts made.

This model was fit again without the standout student, despite the standout student not having high influence or leverage. This was done to ensure no relationships were being overestimated due to this student, who was consistently an outlier in many categories, including total posts and total social presence.

Table 9: Results of Model 1a, without standout student

Variable	Coefficient Estimate	P-Value
Intercept	62.3040	<0.0001
Total Posts	0.0932	0.0528
Proportion of Cohesive SP	31.8541	0.0220

When Model 1 is recalculated without the standout student, estimates remain similar to the original model. This is expected because the student was not an influential point.

However, what changes in this model is the strength of the evidence. There is still strong evidence for the relationship between proportion of cohesive social presence and final grade, but the evidence of the relationship between total posts and final grade is weaker. Though the p-value is larger than 0.05, there is still fairly strong evidence of the relationship. This does not change the results of this model, just the *strength* of our results.

Next, the focus was shifted to questions that arose during the coding process. The aim was to explore potential relationships between final course grade and the use of the agreement and self-disclosure social presence indicators. Thus, a model using proportion of disclosure and proportion of agreement as predictors of final course grade was fit. Proportions were used to preemptively avoid multicollinearity and provide more information in the model as the total posts variable was not included. This model found that proportion of self-disclosure was significantly associated with final course grade, and proportion of agreement was not.

This resulted in another final model: proportion of self-disclosure as a predictor of final course grade. This model will be called Model 2. Model 2 was also fit twice- once with all students and once without the standout student. Both times, model assumptions were not violated and found very strong evidence of a *negative* association between proportion of self-disclosure and final course grade.

Table 10: Results of Model 2

Variable	Coefficient Estimate	P-Value
Intercept	92.828	<0.0001
Proportion of Self-Disclosure	-57.869	0.0009

Model 2 suggests a statistically significant negative relationship between proportion of self-disclosure in posts across the quarter and final course grade. This model estimates that each 0.1 (10% points) increase in proportion of self-disclosure is associated with a decrease of 5.78 percentage points in final course grade. Very strong evidence of this relationship is found with a p-value of 0.0009.

Table 11: Results of Model 2a, without standout student

Variable	Coefficient Estimate	P-Value
Intercept	91.218	<0.0001
Proportion of Self-Disclosure	-50.817	0.00428

Model 2a has a larger change in the coefficient than the previous model when calculated without the standout student, but this change is still relatively small in the context of a proportion. The strength of evidence does change similarly to the previous model, however, unlike Model 1, there is still very strong evidence of the relationship between proportion of self-disclosure and final grade. This is likely because the standout student was *not* a standout in the proportion of self-disclosure variable, only in the final grade variable.

Overall, the linear models provide strong evidence for relationships between total social presence and final grade, total posts and final grade, proportion of cohesive social presence and final grade, and proportion of self-disclosure and final grade.

Chapter 5
CONCLUSION

This thesis investigates social presence in Collaborative Keys (CKs) within asynchronous online statistics courses to understand its impact on student performance, utilizing the Community of Inquiry (CoI) framework. Data from a Cal Poly statistics course was analyzed by coding student responses for social presence indicators in three categories (affective, interactive, cohesive) and examining their relationship with final course grades. The coded responses were analyzed to identify social presence instances and their relationship with students' final course grades through descriptive associations and linear models. Key findings indicate that higher-performing students had more posts and social presence, with cohesive presence showing a strong positive correlation with performance, while self-disclosure had a negative correlation.

5.1 Discussion

The results of this analysis provide preliminary evidence of a possible association between social presence and statistical performance. The more students engage with the CKs, the more posts students will add to the discussion section of the assignment. Due to the positive association between total number of posts and social presence display, the more students engage with the CKs, the more opportunities there will be for them to interact with their group members and display social presence. This analysis suggests that the more effort a student invested into CKs, the better their course outcome was.

Additionally, the relationship between cohesive social presence and final grade suggests that the more students see their group as one entity, the higher they tend to perform in the

course. This aspect of Collaborative Keys could be improved by ensuring students remain in the same group throughout the quarter, unless extenuating circumstances are present. It is possible that the more students feel like a group unit, the more supported they feel in the class, allowing for better performance outcomes. A relationship between self-disclosure and final course grade was also found, suggesting that students who express confusion, uncertainty, or address mistakes at a higher rate than other students tend to have lower course performance.

Previous research has found relationships between affective social presence and student performance in group work (Guo et al., 2021), but this analysis found no evidence of such a relationship. The research done by Guo et al. (2021) looked at more private student interactions over social media platforms. This aspect of privacy and interacting outside of an assigned discussion could prompt students to feel safer to project themselves as "real people" and express humor, emotions, and vulnerability. It could be beneficial to ensure students completing CKs are aware that their *discussions* will *not* be counted towards a grade, only their final responses.

The use of social presence overtime displayed some interesting patterns. In the adjusted score for overall social presence, group 6 had a steeper increase starting at CK 5.2 (week 6) than other groups. When investigating this pattern, it was found that two students in the group increased their participation in the assignments after this week, resulting in more total posts and social presence. Additionally, the adjusted affective score- which reflects expressing emotion, humor and self-disclosure- for all groups dipped around the same CK (5.2, week 6). This dip was fairly large for the majority of groups, with only two groups (4 and 14) showing smaller dips. This is concurrent with the material of the

class getting more complicated, including comparing two populations. Around this time, the class-average score for end of unit quizzes drops from consistently being in the high 80s to remaining in the low 80s for the rest of the quarter. After this dip, the adjusted affective score increased for many of the groups. These changes in social presence could be explained by students responding to poor grades by increasing effort in the CKs and course overall.

5.2 Further research

Research regarding the efficacy of Collaborative Keys in promoting social presence in asynchronous classrooms is far from complete. This analysis begins to show results of social presence being utilized in the assignment and its relationship with student performance but also raises many more questions to be answered with further research.

While some specific social presence indicators and categories are specifically investigated in this analysis, many are not. Specifically, it would be beneficial to further investigate the use of agreement in this assignment. Agreement is by far the most used indicator by this class. Many students had some form of agreement in most of their posts. This is not necessarily a good thing. There were some instances of agreement on answers to questions that were unwarranted - like stating that answers agreed with one another when they were largely different. Agreement seemed to be a fallback answer at times. Its large amount of usage makes it difficult to immediately uncover relationships, but there is likely some relationship between agreement and student performance, potentially a nonlinear one.

The cohesive category of social presence was heavily discussed in this analysis, but further research should still be done regarding this category. The cohesive social presence indicators are using group pronouns (i.e. “we”), referring to group mates by name and interactions that are purely social - such as greetings. When working as a group it is possible that these aspects of social interaction come naturally and are automatic for students when discussing group work, especially referring to students by name and use of group pronouns. Group pronoun use can be encouraged by coursework in statistics with certain phrasings of conclusions (e.g., *We* are 95% confident that…), so it could be interesting to determine whether “*we*” is seen by students as statistical language. Further research into this type of social presence could help future educators and instructors to better understand how students interact with each other in an educational setting and therefore allow for better accommodations for groups.

There are many more facets of student performance that should be researched further. The analysis of week-to-week performance in assignments unrelated to CKs, such as weekly quizzes, could provide further insight to exactly how social presence indicators and student performance are related. This could provide interesting insight on how students interact with one another and the material when faced with more difficult assignments. Additionally, further investigation into students’ attitudes about statistics as a response (rather than a performance metric) would allow for the assignment to be tailored further to suit student’s needs.

A notable analysis that should be continued within this project is the group effect on social interactions. Student group clearly accounts for some variation in how students interact with one another but was not accounted for in the inferential models that were

created. To account for this, groups could be included as a predictor in the model, or a multi-level model including group as a cluster could be fit to measure the variability student group accounts for. Ultimately, these models would provide further insight into how students interact and provide valuable insight for instructors.

Lastly, further research into the other presences proposed by the CoI, cognitive and teaching, are necessary to understand the full student experience with CKs. Coding regarding teaching presence was completed for these assignments but not used in this analysis. It is possible to code for cognitive presence, seen in Guo et al. (2021) and this would provide insight into students' thought process. Any relationship between teaching, cognitive, and social presences and student performance is crucial to understand to provide the best support for students in a sometimes isolating asynchronous setting.

Overall, this work provides a baseline for further research to be done regarding the Collaborative Key assignments. The results of this study are promising but preliminary and should be replicated with a larger sample size.

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