The Relation Among Gender, Language, and Posting Type in Online Chemistry Course Discussion Forums

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ABSTRACT

This study explored gendered language used in an online chemistry course's discussion forums, to understand how using gendered language might help or hinder learning outcomes, while considering the goal of various posting structures required in the course. Findings revealed that although gendered-language use did not differ between men and women, gendered forms of language were widely used throughout the forums. The use of gendered language appeared strategic, however, and reliably varied by the goal of the discussion post (i.e., posting a solution to a homework problem, asking a question, or answering a question). Ultimately, gender, language and posting type were found to be related to final grade.

CCS CONCEPTS

• **Social and professional topics → Gender**.

KEYWORDS

STEM education, Gendered language, Online discussion

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1 INTRODUCTION

Best practices in teaching online typically emphasize the need to provide a space for students to interact so that students can build community [1, 42, 63]. Indeed, substantial work has been devoted to exploring the importance of developing community in online settings to prevent dropping out (e.g., [3, 39]), raise course satisfaction [21, 43], strengthen cooperation [4, 12, 29], increase lines of support [22, 54] and promote feelings of belonging [8, 27] to aid learning [34, 61]. As proof, participation in discussion forums tends to be correlated with higher grades (e.g., [37, 51, 72]. Thus, in the context of online courses, discussion forums serve dual, intertwined purposes of creating community while also improving learning outcomes.

Discussion forums may be particularly helpful for women, given that women have relatively higher needs for affiliation [20], and forums cater to this by assisting with community building through interaction. Because women are significantly underrepresented in Science, Technology, Engineering, and Math STEM fields, leveraging forums in STEM courses may be especially beneficial to women [26].

Simply offering the discussion forums does not necessarily guarantee positive outcomes for either men or women: instructors need to implement them thoughtfully to maximize outcomes (e.g., [37, 62]). And, once implemented, students need to engage with them productively to avoid negative outcomes. For example, the ways in which students engage with each other may preclude them from maximizing learning outcomes, especially if the language that they use is off-putting or disparaging, which may be associated with traditional gendered language categories. Because of the ubiquity of gendered language [69] in online STEM discussion forums, we examined gendered language used in online discussion forums in relation to learning outcomes. We also investigated the influence of the context in which gendered language was used, by examining gendered language's interaction with the particular structure of the discussion forums in relation to learning outcomes.

2 LITERATURE REVIEW

2.1 Online learning for women in STEM

The online space seems to be a draw for women in STEM, as evidenced by the higher proportions of women enrolled in online vs. in-person STEM contexts [15, 47], but they are more likely to withdraw from online STEM courses than men [74]. The attrition rate for women in STEM programs often has been attributed to isolation [10, 28]. Margolis and Fisher [41] point to a non-inclusive culture in STEM classes, leading to a sense of isolation and a lack of confidence, thus exacerbating the paucity of women in STEM. By incorporating features that might strengthen communities of learning [35], online courses have the potential to reduce feelings of isolation. In particular, forum discussions explicitly tackle the issue of the isolated learner; they not only promote deeper understanding but also may lead to feelings of belonging [32, 70, 76]. If women in STEM felt more welcomed, more empowered, and more connected in their STEM college courses—which potentially can happen by increasing engagement in the discussion forums—the chances for eventual success in STEM could be improved for these students. Research on Massive Open Online Courses (MOOCs) suggest that women are comfortable participating in discussion forums,

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as they participate at greater rates than their male peers [16]. Understanding how women interact in discussion forums in online contexts other than in MOOCs will help us understand the ways in which discussion forums can be leveraged to help women succeed in online STEM content; for this reason, we have chosen to explore gendered communication that students use in online college STEM courses.

2.2 Gendered language use and discussion forums

Self-identified men and self-identified women can often express themselves differently [11]. Patterned differences in words, phrases, and sentences have led researchers to categorize men's communication as generally dominant and aggressive (a "report" style of communicating) and women's as generally submissive and affiliative (a "rapport" style of communicating) [69]; such patterns are what we refer to as gendered language. Importantly, these styles signify power differences, leading to real-world power differentials between men and women in both the private and public spheres [25, 44].

Linguistic markings may reveal one's status, thus further influencing the collaborative experience. According to Cho et al. [14], social attributes carry with them stereotypes and power rankings,

> "… some individuals may outperform their peers, because they occupy more structurally advantageous positions than others in social networks. In general, social network studies … demonstrate that network positions have significant impacts on individual and organizational outcomes because the structure of social interactions enhances or constrain access to valued resources such as task advice, strategic information, social supports, etc" [p. 8].

Given that students taking up and owning ideas originally presented by others is an important part of learning (e.g., [6, 7] and is what occurs on the discussion forums, examining the language used to share those ideas is crucial. Beuchot and Bullen [9] echo this, finding that the social content of messages posted on online discussion forums is related to the amount of interactive participation. Furthermore, language has the potential to be a marker of one's social status, which in turn can influence students' reactions to—and ultimately access to—support and the sharing of information in the online environment [14].

Sullivan et al. [67] sought to investigate whether gendered discourse would negatively affect collaboration in online science discussions. Although they found that each gender tended to abide by their discourse norms, the researchers did not find that the discourse styles influenced collaboration. The researchers had hypothesized that ideas presented in terms of a female-discourse style would be ignored more than those ideas presented in terms of a male-discourse style, but they found no gender bias. Lin et al. [38] found that although there were gendered communication patterns in online collaborative interactions, there was no difference in participation between men and women. Such findings suggest that the online environment might thwart gendered language's stereotypical effects.

2.3 Discussion forums and interactivity

Language is only one component of understanding how discussion forums may help students succeed online. Another strand of research on online discussion forums focuses on the amount of times that students post to discussion forums in their online courses (e.g., [13, 55, 59]). These studies generally find that increased amounts of posting results in higher grades (e.g., [51, 52, 72]), and higher cognitive engagement [2], and students who post more frequently also perceive that they are more satisfied with the courses and report learning more [68].

2.4 Technological pedagogical content knowledge

Creating posts and interacting with others does not assure learning. Davies and Graff [18] argued that the quality of the posts may determine learning outcomes. This quality may emerge from providing students with goal-based activities [19], a focus on difficult topics [73], and structure [23]. Indeed, Salter and Conneely [62] found higher rates of student engagement when discussion forums provided clear structure compared to open-ended forums.

Developing forum structures that foster learning requires instructors' thoughtful use of technological pedagogical content knowledge (TPACK). Mishra and Koehler [48], following Shulman [65], argued that instructors need to implement their understanding of which technological tools are appropriate when implementing pedagogical strategies. Using technology (e.g., online discussion forums) while ignoring the pedagogical knowledge aspect (e.g., not thinking about how the forums should be structured) can easily result in misunderstandings of or disengagement with content [33].

When, however, forums are offered with intent, tied to goals, and serve as a conduit for delivering a pedagogical strategy, learning can flourish. Dennen [19] found that discussion forum activities involving perspective taking via sharing examples and making connections to outside concepts resulted in deep meaning making. Darabi et al. [17] echoed this finding, explaining that reaching higher levels of critical thinking in discussion forums can happen by immersing students in authentic scenarios that require them to take different perspectives. Tibi [71] highlights students' heightened attitude and positive disposition toward discussion forums when they are structured.

These few examples point to the importance of uncovering principles for structuring online discussion forums for best learning outcomes [40]. Toward this end, we investigated how thoughtfully and intentionally structuring forums, based on cognitive theories of learning, was related to student contributions on those forums and to students' grades in the course. These forums were structured so that students asked questions, answered others' questions, and provided solutions to quiz-like homework problems. Each of these structures is derived from cognitive theories of learning and research on best pedagogical practices, as described below.

Asking Questions. Asking questions is often a sign that students may be experiencing conflict between what they know and what they need to know or what they recently learned, thereby motivating them to resolve the conflict through problem solving, reasoning, and questioning. This process of restoring to a state of cognitive equilibrium promotes student learning [24].

Answering Questions. The benefits of answering questions derive from the positive effects that accrue from providing explanations (see, e.g., [5, 30, 60, 66]). Having to provide explanations and to teach others promotes understanding [46, 56, 57].

Posting Solutions to Quiz-like Homework Problems. A potential benefit of this posting type lies in the way it takes advantage of the testing effect, by frequently engaging with and practicing the material. Doing so provides formative assessment, where both the instructor and students can evaluate what they do and do not understand [58]. Additionally, when solutions to the homework problems require the generation of answers rather than the recognition and selection of the answers from a list, students are much more likely to learn the material [30, 45]. By posting publicly, students can solicit written feedback from other students and compare their results with others to get feedback on what is going well and what needs improving.

2.5 Research questions

We sought to gain insight into differences between men and women, the language they used, and the ways in which the ways they could post to the course discussion forum played a role in the well-documented differences between men and women in STEM. We were particularly interested in whether we might document differences in language use between men and women that might reflect and promote student engagement and success in the course. More particularly, we sought to (a) understand whether men and women behaved similarly or differently as they navigated where they contributed to the discussion; (b) see whether language form (male- vs. female-typical language) followed function (posing a question, answering another's question, or solving a quiz-like homework problem) and (c) examined whether men and women differed in their language used across different forum posting structures (in other words, do we see differences in men's vs. women's language use that might be sensitive to the function of the post?). And ultimately, we wanted to know if observed differences were related to final grades.

To get at these interrelated issues, we asked three research questions:

(1) Do men and women differ in their use of gendered language on discussion forums?
(2) Do we see differences across the 3 forum types in (a) men vs. women, (b) use of gendered (masculine vs. feminine) language, and (c) men's and women's use of gendered language?
(3) Are observed differences related to final grades? We break this down by asking if there is a relation between final grades (a) and identifying as a man or woman? (b) based on forum structure (type of post)? (c) based on language use? and (d) for language within each posting type?

3 METHOD

We received approval from our institution's Office for the Protection for Human Subjects to conduct the research described herein.

3.1 Participants

Data were collected from the discussion assignments from students enrolled in four semesters of an introductory online chemistry course. Across the four semesters, a total of 368 total students enrolled, only 345 of whom were unique (18 students had enrolled in two semesters and 3 students had enrolled in three semesters). From these, we located 74 total drops, but because there were 8 students who had dropped the course twice, only 66 unique students dropped (37 women and 29 men). This left 271 unique students who were enrolled for the entire semester. We had incomplete data for 24 of the students, leaving a total of 247 students for analysis (132 women and 115 men). We note that the incomplete data came from a small number of students who did not post any comment. A staff member with clearance to access FERPA-protected data replaced any personally identifiable information with a random hash on the discussion posts and created a key detailing the gender that corresponded with each of the random hashes.

3.2 Data set

Students generated 3,404 posts throughout the four semesters. These posts constitute the corpus for analysis. Contributing to the discussions accounted for 5% of students' final grades.

Each week, the instructor created 4-5 discussions forums, with each forum consisting of an exam-like problem. Students chose in which forum to participate and they were required either to (a) post a solution to the initial problem, (b) post a question about the problem, or (c) answer a question that had been posted by another student. Students were only required to post once each week, although they were permitted to participate more if they chose to do so. The instructor's intended goal of this assignment, as posted on the syllabus, was to have students "learn how to approach challenging problems from other student explanations, and by teaching other students."

3.3 Data analysis

Gender. Students were classified as male or female, based on self-identification data when enrolling at the University.

Grades. To comply with FERPA requirements so that students' identities would not be revealed, final grades were collapsed from A, B, C, D, F, and W (withdraw) into two categories: (1) an A or B or (2) a C or below.

Posting Type. classified each post as a solution, question, or answer (see definitions provided in Data Set) in an automated manner by considering the reply depth of a post in the discussion thread as well as whether a question mark was present. If a question mark was present, the post was coded as a question, despite the reply depth. If the post did not contain a question and was the first statement in a thread, we coded it as a solution. If the post did not contain a question and appeared in at least the second level of reply depth of the discussion thread, we coded it as a solution. The posting types were mutually exclusive; therefore, each post could only belong to one of the three types. To verify this system, humans coded 20% of them and compared this to automated, machine coding. Reliability between the human and machine coding indicated substantial agreement (Cohen's $\kappa = .75$).

Text Analysis. To analyse the gendered language employed in the discussion forums, we used Linguistic Inquiry and Word Count 2015 (LIWC; [53]), a computerized text analysis program that outputs the percentage of words in a given text that fall into one or

more of over 80 linguistic (e.g., pronouns, conjunctions), psychological (e.g., anger, achievement), and topical categories (e.g., money, religion). LIWC used a corpus of more than 500,000 texts, which ranged from tweets to novels, to derive these categories. LIWC 2015 also includes summary variables and we used 3 of these in our investigation: analytical thinking (e.g., presenting logical thinking; [53]), clout (e.g., showcasing confidence and expertise; [31], and authenticity (e.g., displaying openness and honesty; [50]. For these summary variables, LIWC only generates a rating, rather than a count. Following the LIWC analysis of gendered language of Newman et al. [49], this study uses the categories of Analytic, Numbers, Certainty, and Clout to classify masculine language and the categories of Pronouns, Authenticity, Social, Affiliation, Discrepancy, and Tentative to classify feminine language. For examples of these categories, see Appendix A.

We analyzed each post for LIWC categories, assigning a median score to each student's posting type for the relevant LIWC categories.

4 RESULTS

We present results as answers to earlier posed research questions, utilizing data from all semesters due to the absence of differences between them. The research questions build on one another, but because a model incorporating all variables would violate assumptions of independence, we tested each question individually.

Research Question 1: Do men and women differ in their use of gendered language in the discussion forums?

Because of the nonparametric nature of the data, we did a pairwise comparison of each gender for each LIWC category using a Mann-Whitney U test. There were no gender differences for any of the categories (see Table 1).

Research Question 2: Do we see differences—(a) in men vs. women, (b) between use of masculine vs. feminine language, and (c) in men's and women's use of gendered language—across the 3 types of forums?

We ran a Kruskal-Wallis test to determine if the forum types differed in general between men and women and then conducted pairwise comparisons of gender for each forum type to see if any forum type in particular varied. Doing this, we found no difference between men and women in their types of posts: asking questions, $\chi^2(1) = 2.41$, $p = .12$; answering questions, $\chi^2(1) = 2.80$, $p = .09$; or posting solutions, $\chi^2(1) = .15$, $p = .70$.

Next, we ran a Related-Samples Friedman's Two-Way Analysis of Variance test with a Bonferroni adjusted alpha level of .0045 (.05/11) to determine if there were differences in the LIWC categories employed within different posting categories (see Table 2 for the median for each category, by posting type). Language use was statistically significantly different between posting types for all categories except for clout: Word Count: $\chi^2(2) = 33.38$, $p = .000$; Analytic: $\chi^2(2) = 52.74$, $p = .000$; Clout: $\chi^2(2) = 2.841$, $p = .245$; Authentic: $\chi^2(2) = 43.98$, $p = .000$; Pronoun: $\chi^2(2) = 63.02$, $p = .000$, Number: $\chi^2(2) = 61.63$, $p = .000$, Social: $\chi^2(2) = 63.10$, $p = .000$, Discrepancy: $\chi^2(2) = 21.56$ $p = .000$; Tentative: $\chi^2(2) = 29.12$, $p = .000$; Certainty, $\chi^2(2) = 25.45$, $p = .000$, Affiliation: $\chi^2(2) = 30.451$, $p = .000$. With the exceptions of Analytic and Number, every category was used significantly more when asking questions compared to answering questions or posting solutions. Analytic and Number were used significantly more when posting solutions, compared to both asking questions and answering questions.

Finally, we ran a Related-Samples Friedman's Two-Way Analysis of Variance to investigate whether men and women differed in their language used across different posting types (see Table 2). Men and women behaved differently in terms of language use across the three posting structures in about half of the categories: Authentic [$\chi^2(2) = 14.80$, $p < .001$], Analytic [$\chi^2(2) = 23.33$, $p < .001$], Tentative [$\chi^2(2) = 18.88$, $p < .001$], Certainty [$\chi^2(2) = 11.34$, $p < .001$], and Affiliation [$\chi^2(2) = 29.78$, $p < .001$]. In these five instances, women used more of that language marker when asking questions than when answering questions or posting solutions, but men did not. In the case of Word Count, Pronouns, Number, and Discrepancy, men and women both used these language markers more when asking questions than when answering questions or posting solutions (although we note that when using the Bonferroni correction, these results no longer meet our significance criteria). In addition, men and women had similar use of Clout across posting types.

Research Question 3: Are observed differences related to final grades? (a) for men and women? (b) based on forum structure (type of post)? (c) based on language use? and (d) for language within each posting type?

We first asked whether men and women differed in their final grades. Among all students who completed the course across all semesters, there were 120 final grades of an A or B and 127 final grades of a C or below. A χ^2 test indicated that the high grades and low grades were not equally distributed between men and women, $\chi^2(1) = 9.18$, $p < .01$, with men more likely to earn a higher grade (N = 71, 62% of men) than a lower grade; and women less likely to earn a higher grade (N = 56, 42% of women) than a lower grade.

Next, we explored which features of participation (types of posts and types of language) were associated with higher grades. First, we used a Kruskal-Wallis test to determine whether posting type was related to final grade in general and then we conducted pairwise comparisons of final grade for each forum type to see if any forum type in particular varied. Posting solutions, $\chi^2(1) = 4.30$, $p < .05$, and answering others' questions $\chi^2(1) = 7.69$, $p < .01$ were both significantly related to earning higher grades. Asking questions was not significantly related to final grade.

Using a Kruskal-Wallis test to examine the relation between use of LIWC language features and final grade first as a whole and then through pairwise comparisons (see Table 3), we found that students earning an A or B had significantly higher use of two LIWC categories compared to those earning a C or below: Word Count: $\chi^2(1) = 17.65$, $p = .003$ and Number $\chi^2(1) = 14.54$, $p < .001$ (see Table 3). Both of these results remain significant, after using the Bonferroni correction (i.e., p values remain below .0045).

We then ran a Mann-Whitney U test to conduct pairwise comparisons to determine if there were differences in grade for the LIWC categories, within posting types (see Table 3). Students who earned higher grades had higher word counts when asking questions ($U = 635$, $p = .03$) and posting solutions ($U = 2539$, $p = .00$) than students with lower grades, and they also used more numbers when posting answers ($U = 897.5$, $p = .02$) and asking questions ($U = 589.5$, $p = .05$). We found that although Authentic and Affiliative language were not generally differentially used between higher and lower

grade earners, students earning lower grades used Authentic language significantly more when asking questions (U = 589.5, p = .01) and used Affiliative language significantly less when asking questions (U = 424.5, p = .02). However, most of these results must be taken under caution because they lose their significance when performing the Bonferroni correction (i.e., p values fall above .0045). No differences in final grades were found for other posting types within each of the grade categories; rather language was used in similar ways across posting types within each grade category.

5 DISCUSSION

This study examined the interplay between gender, language, and posting types, as well as the relationship of each of these to final grade. We found that although elements of gendered discourse permeated the discussion forums, the use of gendered discourse was not related to a student's gender. Such findings are in line with those of Lawson [36] that found that women in male-dominated majors do not disproportionately experience sexist events during class compared to men in those majors or women in gender-neural majors. Although not delineated by gender, gendered language in our study did, however, significantly relate to what type of post the student produced and was also related to students' final grades.

5.1 Ways in which gender and gendered language relate to grades

Unlike others (e.g., [75]), we did not find that women performed significantly better in online courses than men. In this particular online course, women performed worse than men, just as they do in face-to-face classes [75].

We found that men earned higher grades than women. This echoes the findings of Wladis et al. [74] that women are more likely than men to fail online STEM courses. Although this does not seem to be related to language use, other aspects of community could be the culprit. One possible explanation and future line of research involves examining the instructor's interactions in the discussion forum. According to Swan [68], positive outcomes correlate with not

Table 1: Median Counts of LIWC Categories by Gender

	LIWC Category	Median	Mann-Whitney U	Z	IQR	p value
Summary Categories	**Analytic**		6849	-1.323		0.187
	Men	86.5			18.15	
	Women	84.4			29.25	
	Clout		7255	-0.598		0.358
	Men	48.4			15.97	
	Women	49.7			13.48	
	Authenticity		7430	-0.285		0.776
	Men	9.5			21.59	
	Women	9.5			37.47	
Linguistic Categories	**Pronoun**		7259	-0.591		0.554
	Men	29			54	
	Women	20.5			56	
	Number		7201.5	-0.694		0.488
	Men	63			81	
	Women	60			0	
	Word Count		7157	-0.773		0.439
	Men	451			601	
	Women	424			593	
Psychological Categories	**Social Processes**		7493	-0.173		0.862
	Men	12			24	
	Women	12			25	
	Discrepancy		7429	-0.289		0.773
	Men	4			8	
	Women	4			8	
	Tentative		7565.6	-0.044		0.965
	Men	7			10	
	Women	6			12	
	Certainty		7139	-0.81		0.418
	Men	4			7	
	Women	4			7	
	Affiliation		7202.5	-0.697		0.486
	Men	6			10	
	Women	4			11	

only peer interaction but also instructor interaction. Such findings provide support for Garrison and Cleveland-Innes [23] Community of Inquiry model, highlighting the need for others in learning.

We found that women generally did not use a rapport style of communication, and thus this does not seem to be associated with their lower performance. Perhaps the course structure—and particularly the structure required for the forums—played a greater role in use of gendered language than a student's gender. If this is the case, replicating the structure of the forums in other courses (especially with different STEM content) could provide insight into how gendered language plays a role—or not—in online STEM college courses.

The only way in which women's language use differed from men's language use was in women's differential use of Authentic, Tentative, Affiliation, and Certainty across posting type. Women used Authentic language more when posting solutions than with the other posting types. Interestingly, as explored in Research Question 3, using Authentic language while posting solutions was not associated with final grade. Thus, their use of Authentic language for this posting type did not appear to be of major consequence in terms of grade potential.

Furthermore, women used more Tentative, Affiliation, and Certainty when asking questions compared to other posting types. Important to note is that question asking was not related to final grade. Thus, again, women's linguistic engagement within this

Table 2: Median Counts of LIWC Categories, by Posting Type, for the Full Sample, and for Women and Men, separately. Note: * corresponds to p = .000, comparing differential use of language between the different posting structures (Questions, Answers, and Solutions); when the structures significantly differ from one another either among the whole sample or between men and women, it is noted next to the Questions category. When comparing the different posting structures when p is still significant but when p > .001, we report the exact p-values and note these in the appropriate column, in the row with data from Question Postings.

		Full Sample	Women	Men
LIWC Category	Posting type	median	median	median
Word Count	Questions	52.0*	53.8*	49.0 (p = .035)
	Answers	31.7	28.6	33.1
	Solutions	43.6	41.1	45.7
Analytic	Questions	53.3*	52.1*	60.9
	Answers	64.9	64.9	65.4
	Solutions	85.4	85.3	85.5
Clout	Questions	50.0	50.4	48.9
	Answers	53.2	53.5	50.0
	Solutions	48.0	47.2	49.1
Authentic	Questions	41.3*	43.5*	39.5
	Answers	30.5	34.2	26.9
	Solutions	17.0	15.9	17.3
Pronoun	Questions	6.5*	7.2*	6.0 (p = .001)
	Answers	3.4	3.5	3.5
	Solutions	2.1	1.9	2.4
Number	Questions	1.6*	1.7 (p = .009)	1.5 (p = .028)
	Answers	2.0	1.8	2.5
	Solutions	7.8	8.0	7.6
Social	Questions	3.0*	3.0*	3.0 (p = .004)
	Answers	1.6	1.7	1.6
	Solutions	0.9	0.8	0.9
Discrepancy	Questions	0.8*	0.8 (p = .001)	0.8 (p = .011)
	Answers	0.4	0.5	0.3
	Solutions	0.3	0.3	0.3
Tentative	Questions	1.3*	1.3*	1.3
	Answers	0.6	0.6	0.6
	Solutions	0.5	0.5	0.6
Certainty	Questions	0.7*	0.7 (p = .003)	0.6
	Answers	0.3	0.3	0.3
	Solutions	0.3	0.2	0.3
Affiliation	Questions	1.2*	1.2*	1.3
	Answers	0.3	0.3	0.4
	Solutions	0.3	0.3	0.4

Table 3: Median Counts of LIWC Categories, by Grade and by Posting Type.
Note: † denotes that the reported p-values are comparing grades *within each* posting type; ‡ denotes that the reported p-values are comparing grades *between all* posting types.

LIWC Category	Posting type	Grade: A or B	Grade C or Below
		Median	Median
Word Count	All posts (p = .003)†	45.7	34.9
	Questions	55.4 (p=.027)‡	46.0
	Answers	35.8	28.1
	Solutions	49.0 (p=.049)‡	41.2
Analytic	All posts	73.2	67.5
	Questions	60.8	50.4
	Answers	66.4	62.9
	Solutions	85.7	82.2
Clout	All posts	50.3	48.3
	Questions	54.0	45.0
	Answers	54.8	50.0
	Solutions	48.6	47.4
Authentic	All Posts	23.1	25.5
	Questions	33.1	47.3 (p = .009)‡
	Answers	28.0	37.4
	Solutions	16.7	17.5
Pronoun	All Post	3.5	3.1
	Questions	7.0	6.4
	Answers	3.7	3.2
	Solutions	2.3	1.9
Number	All Posts (p= .000)†	6.0	4.6
	Questions	2.0 (p=.046)	1.4
	Answers	2.6 (p=.018)‡	1.3
	Solutions	8.3	7.4
Social	All Posts	1.7	1.3
	Questions	3.0	2.9
	Answers	1.7	1.2
	Solutions	0.9	0.8
Discrepancy	All Posts	0.5	0.7
	Questions	1.0	0.8
	Answers	0.4	0.4
	Solutions	0.3	0.4
Tentative	All Posts	0.8	0.8
	Questions	1.2	1.4
	Answers	0.7	0.6
	Solutions	0.6	0.5
Certainty	All Posts	0.4	0.5
	Questions	0.5	0.7
	Answers	0.3	0.3
	Solutions	0.3	0.3
Affiliation	All Posts	0.8	0.6
	Questions	1.3 (p= .015)‡	0.8
	Answers	0.5	0.2
	Solutions	0.4	0.3

posting type did not appear to be consequential in terms of final grade. Moreover, although we found differences in these categories, the overall frequency was quite low, which further suggests that these categories may not be of practical significance.

5.2 Language and posting types

Although a student's gender was not predictive of use of gendered language, some components of gendered language were related to

posting type. This suggests that students were using language in purposeful ways.

We note that students who earned a higher grade used Numbers significantly more than their lower-grade-earning peers when asking or answering questions in particular. We reckon that including Numbers adds specificity to students' posts; less detail may indicate less understanding. A practical implication of this finding is that students might benefit when instructors encourage students to use numbers when asking and answering questions. This advice could be helpful for other courses that also have heavy numerical components.

Likewise, students who earned higher grades had higher word counts when asking questions and posting solutions. Instructors should take note of this and might get students to think more deeply about the course content by requiring a minimum word count. Requiring longer posts might push students to explore their thoughts and be more thorough in their explanations; future investigations in which students are required to produce posts with different lengths could provide an answer to whether this would produce both longer and better explanations, and whether each is related to outcomes. Having students focus on quality and length of posts may have a differential impact on students' learning compared to having them focus on the frequency of posting [64].

5.3 Posting types

Posting solutions and answers to other students' questions was associated with earning a higher grade compared to asking questions. Thus, instructors may consider requiring at least some minimum number of posts that provide solutions to homework problems or answering students' questions.

5.4 Limitations and future directions

Requiring students to post in an online forum resulted in almost all students participating every week. This requirement may have been instrumental in supporting relatively equal participation by men and women. This is notable in the context of a college STEM course, in a discipline dominated by men. However, the fact that men and women used gendered language similarly was unexpected. Future research should take care to understand how course structure impacts students' participation including, but not limited to, use of gendered language. We expect that participation—including the way in which the students communicate with each other, and which may be influenced by course structure and instructional choices—impacts students' engagement with and learning in the course.

This study cannot speak to the directionality of the results. For example, it is not clear if using fewer words resulted in lower grades, or if being on the path to earning a lower grade resulted in using fewer words. Likewise, gathering more background information on students (e.g., ACT score, major, etc.) may provide more information on why we found the observed differences.

Because this study only considered one course, we recommend that future studies examine courses with a similar structure. This should provide a better understanding of how generalizable the results of this study are.

Importantly, this study relied on LIWC to capture gendered language. Other approaches may provide different insights into why certain language categories are associated with lower grades for certain posting types.

Future studies should examine the question-asking posts to understand why this posting type was not associated with final grade. Students who are struggling may have more questions, but students who have high enough metacognitive awareness and reflectivity to engage in help-seeking behaviour may ask questions and earn a higher grade. Examining question-asking patterns across the semester and seeing if the questions get answered is important in understanding this. Follow-up studies may also examine the content of the questions to see if richer questions might be associated with higher grades (as is speculated here, based on the language used).

Finally, we have recommendations related to use of artificial intelligence in online discussion forums. We have already recommended that students might benefit when instructors, for example, encourage students to include quantitative support while asking and answering questions. Additionally, given the relation of longer posts to student grades, we recommended that investigators examine whether longer posts might get students to think more deeply about course content. Taken together, we see potential for using AI-based conversational agents using large language models to moderate course forums and nudge students based on the nature of their posts in ways that might positively impact content-related understanding. From a learning analytics perspective, this study positively contributes to the significant body of literature that leverages text analysis to relate the nature of discussion forum participation to their backgrounds and learning outcomes.

5.5 Conclusion

We examined how discussion forums are related to course outcomes. Specifically, we explored how gender, gendered language, and posting type related to final grade. Although men and women used similar language, gender and posting type were both related to final grade; thus, the language that women use is an unlikely contributor to their lower grades. These findings provide even more evidence that students' behaviours in the online environment are different than in the face-to-face environment, and they highlight the need for more research to examine how the online environment supports learning for all students.

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A APPENDIX: LIWC CATEGORIES AND EXAMPLES

Examples of Gendered Language and Corresponding LIWC Categories. Note that items marked with a '*' are summary variables, which are automatically determined by LIWC's proprietary algorithm, so we provide LIWC-generated examples.

Gendered Language Category and whether masculine (promoting report style) or feminine (promoting rapport style)	Corresponding LIWC Category and Category Descriptions	Example
Information Giving (masculine)	Analytic* (critical and logical thinking)	For 29, you have to use the equation lnk = -Ea/R(1/T) + lnA. Slope is equal to -Ea/R and the intercept is equal to lnA. Thus, your equation should look like this now: lnk = -917(1/T) + -.441Next, you need to [find] k by plugging in the temperature given in the problem. Once you have k, then you can plug it into the differential rate. The rate of the equation depends on which order your problem is in. Hope this helps!
	Numbers	G= -1.85kJ Go= -5.15kJ R= 8.314 x = .61149 (the answer was .612, woo!!)
Pronoun (feminine)	Pronoun	Almost this same question was on the recent quiz, yet we weren't given DG standard. I was trying to find it using other equations, but I couldn't quite figure it out. …
Personal/Interpersonal Queries (feminine)	Authenticity* (openness and honesty)	What kind of tripped me up at first was trying to figure out what to do with the amount of water we're given. You have to go back in your brain and remember that molarity=moles/liters, and that the concentration of H+ is molarity. [ac1dbe8447] by multiplying the concentration by the mL of water given, you can get moles.
	Social	Nice to meet you! If you need help with anything, I'm always willing to help!
	Affiliation	Instagram and Facebook (and Snapchat) are how I keep my family and friends up to date on travel. I totally agree with you.
Politeness (feminine)	Discrepancy	I think the concentration of oxygen would have to play a role if we dipped it into liquid oxygen. If you have more concentration of oxygen the Cheetos burn much faster. We could also increase the temperature to increase the rate of the burning of the cheeto also.
Hedging (feminine)	Tentative	I don't think you can use the equation because there is an acid and a base but the conjugate is not present. I think you just figure out what is left over and figure the pH or depending on what species is left.
Confidence (masculine)	Certainty	Yes. Kw is always neutral for water.
	Clout* (confidence and expertise)	I solved for K, which was 0.2963 after rounding. Lastly I plugged everything in to the DeltaG equation (CONVERT -2.00kJ into Joules). DeltaG= (-2000)+(8.314)(298K)In(0.2963)= -5013.68, divide by 1000 to convert back into kJ. DeltaG= -5.014kJ which equals maximum work able to be put in.