Identifying Educational Communication Patterns through Social Media Interactions: The Case of Engineering Education in Oklahoma

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Dr. Tahrima Rouf is a visiting assistant professor at the Stephenson School of Biomedical Engineering (SBME) at the University of Oklahoma (OU). She received her bachelor's degree in chemical engineering from the Bangladesh University of Engineering and Technology and her doctoral degree from Purdue University. Her academic training and research experience have provided her with an excellent background in multiple interdisciplinary fields, including nanotechnology, materials science, chemical engineering, microbiology, and biochemistry. Her independent research program's main goal is to harness the capabilities of nanomaterials for biomedical applications to produce safer and more effective sensing technology and drug delivery. She gained expertise in the controlled synthesis and biochemical characterization of complex protein nanocomposites. In her teaching, she has been dedicated to engaging students in an interactive learning environment, and she is strongly committed to promoting diversity, equity, and inclusion. As a visiting assistant professor at the University of Oklahoma, she continues to build on her previous training in biopolymers and nanoparticles by moving into a biological system that will allow her to address additional questions regarding the utilization of nanomaterials in disease diagnosis and drug delivery. Dr. Rouf's teaching, research, and outreach activities serve as strong evidence of her passion to be successful in making long-term impacts through cutting-edge research and education.

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Abstract

Social media platforms (SMP) are used to share ideas and information in an interactive manner. As such, SMPs are increasingly recognized in engineering education with the potential to support student and faculty participation and engagement. A thorough analysis of social media data can offer meaningful insights on engineering education. By examining social media interactions (i.e., contents of user-generated posts), educators and researchers can identify emerging topics that are gaining traction in the engineering community. Such analysis provides valuable insights into student engagement, revealing what topics or concerns resonate most. It also offers a platform for students to express concerns related to engineering education, which can be instrumental in shaping curricular and pedagogical improvements. Moreover, patterns of networking as evident on social media can inform efforts to foster interdisciplinary learning opportunities. Social media data can also serve as a basis for the effectiveness of educational resources and tools shared online. These insights could also highlight areas where diversity and inclusivity efforts may be lacking, guiding institutions towards more equitable practices. Finally, tracking the post-graduation trajectories of alumni through social media can provide feedback on the real-world applicability and success of engineering programs, enabling continuous refinement and adaptation to industry needs.

Recruiting and retaining engineers in various sectors pose challenges for the state of Oklahoma, as is the case for many other states in the U.S. This shortage can have implications for the state's economy, infrastructure development, and technological advancements. In this study, we analyzed large-scale social media data generated within Oklahoma, obtained from X (colloquially known as Twitter), using several machine learning and natural language processing techniques (i.e., sentiment analysis, bigram analysis, user classification). The extensive data (~110K tweets observed for the year 2020) was gathered using the academic Application Programming Interface (API) that releases complete, unbiased data for researchers to use. Study findings reveal positive sentiments on topics related to engineering majors (biomedical, software), engineering professions, institutional care, distance learning, equity, and tech-related discussions. In contrast, topics related to educational systems for underrepresented groups, loan debts, and some engineering majors (civil, electrical) showed negative sentiments. Understanding such diverse educational communication patterns from social media provides meaningful insights for informing strategies to attract and retain engineering talent and addressing the challenges of recruiting and retaining engineers in Oklahoma and other underserved communities.

Introduction and Motivation

Nearly forty million students use various social media platforms (SMP) [1] and students increasingly use SMPs on their devices since they are generally available and easy to use [2]. Social media users can do different things on various SMPs such as connecting with other students, exchanging helpful links, tagging others in posts, responding to posts by others, and privately messaging their connections. Currently, the use of SMPs are gaining traction from educators and students to connect, team up, and share data [3]. For example, according to a

2015 study, students were more likely to use these social media platforms such as X and Facebook to upload course-related materials and participate in class discussions [4].

SMPs are increasingly recognized in *Engineering Education* (EE) with the potential to support student and faculty participation and engagement. A thorough analysis of social media data can offer valuable insights on EE. By examining social media interactions (i.e., contents of user-generated posts), educators and researchers can identify emerging topics that are gaining traction in the engineering community. Such analysis may provide valuable insights into student engagement, revealing what subjects or topics resonate most. It also offers a platform for students to express concerns related to EE, which can be instrumental in shaping curricular and pedagogical improvements. Moreover, patterns of networking as evident on social media can inform efforts to foster interdisciplinary learning opportunities. Social media data can also serve as a basis for the effectiveness of educational resources and tools shared online. These insights could also highlight areas where diversity and inclusivity efforts may be lacking, guiding institutions towards more equitable practices. Finally, tracking the post-graduation trajectories of alumni through social media can provide feedback on the real-world applicability and success of engineering programs, enabling continuous refinement and adaptation to industry needs.

Oklahoma, like many other states in the U.S., face challenges in recruiting and retaining engineers in various sectors. This shortage can have implications for the state's economy, infrastructure development, and technological advancements. In this study, we analyzed large-scale social media data generated within Oklahoma, obtained from X, using several machine learning and natural language processing techniques including sentiment analysis, bigram analysis, user classification). The extensive data (~110K tweets observed for the year 2020) was gathered using the academic Application Programming Interface (API) that releases complete, unbiased data for researchers to use. In particular, the study explored the social media communication patterns related to EE. The primary research question of this study: *What are the primary discussion topics or concerns that evolve in conversations through social media platforms in the context of engineering education?* Engineering education pathways contain many dimensions, as shown by several studies. One investigation was into the elaboration of self-concept and self-efficacy in engineering education, highlighting differences and suggesting frameworks for improving first-year retention [5]. Another study critically investigates language in discussing inequity, signifying a transformation from "underrepresented minority" to "Excluded Identities" to address systemic issues [6]. Finally, another study with a comprehensive approach created a pathway program aligning with national models to increase engineering graduates through peer support and skill development [7]. Evidence from the literature showed a need for impactful changes to address systemic barriers and ensure equitable representation in non-engineering disciplines, particularly among Black, Latino, and Native American students [8]. Another study emphasized the importance of positive representation in mitigating the adverse outcomes of underrepresentation in performance and belonging in an academic setting [9]. As such, this study classified the main topics and/or concerns (i.e., engineering discipline, pathway, education, profession, equity, and other related concerns) that evolved in social media communication patterns related to EE. The analysis and associated findings presented in this study provide an efficient way to leverage social media to monitor emerging engineering concerns and provide recommendations for future research in this field. The primary research question was further divided into following sub-research questions:

RQ1: *What are the primary concerns expressed through SMPs related to EE disciplines/majors?*
RQ2: *How different social media actors interact and share opinions regarding engineering pathways?*
RQ3: *How do social media user sentiments vary when they discuss about engineering profession?*
RQ4: *What are key concerns related to online EE and their corresponding polarity or sentiments?*
RQ5: *Are there differences in public concerns and opinions expressed in SMPs when they discuss about marginalized groups, diversity, equity and accessibility?*
RQ6: *Do social media users express negative emotions while they discuss student debts and loans?*

Background and Related Work

The widespread use of SMPs like Facebook, X, Reddit, and Instagram has transformed information sharing, surpassing traditional news outlets such as newspapers and TV, while also promoting new user connections and networking opportunities are associated with direct social impacts. Notably, 94 percent of university students prefer these SMPs as an educational, communicational, resource sharing learning platform with diverse audience [10]. SMPs like X (formerly Twitter), Instagram, and Facebook offer a range of routes for communication and teamwork that can enhance learning and student engagement. Online participation in Engineering Education (EE) has become increasingly popular as a research topic in recent years. Social network analysis allows students to examine their participation in an informal atmosphere by equal participation [11]. This literature review on social network usage in EE examines the benefits and challenges of combining social media into teaching practices.

Numerous studies have shown the benefits of utilizing SMPs in EE and also indicate that social media use can increase student participation and collaboration [12-14]. Recent research has examined the most effective ways to use SMPs as an informal learning environment for subjects other than STEM, such as encouraging social assets and resourceful literacy [15]. The article [16] shows how incorporating social media enhances student comprehension of the course topic, student participation in creative projects, and student-teacher engagement. Additional benefits of incorporating social media into education include the ability to follow classes from anywhere at any time and the best possible interaction with the material through peer debate and opinion sharing [17]. In addition to students engaging and exchanging information with subject-topic professionals through social media, using them in engineering classrooms can improve discussion quality, boost student participation, and promote independent learning [18, 19]. Similarly, studies analyzed social media data using Twitter hashtags on activist campaigns for increasing gender equality in the engineering sector [20].

Despite the advantages SMPs' interactive learning environment, studies expressed potential concerns such as distraction and cyberbullying [21]. Likewise, security and privacy concerns could hold some students back from participating in communicating on an SMP platform [22, 23]. Students may be convinced to use SMPs for personal reasons during class, which could be counterproductive to their learning consequences. Some studies with such contrasting views also showed that SMPs may negatively impact student learning outcomes [24]. Studies also discovered that Facebook use during class is considered to be multitasking and causes a lack of focus on the students, adversely affecting their academic performance [25, 26].

However, a recent report found no proof of a connection between virtual entertainment use and students' contributions or scholarly achievements [27].

Although there are mixed observations on how SMPs shaping the online learning environment and complementing in-class learning experiences, SMP use is changing the practices in instructions in engineering education [28]. For STEM students, the growing need for enhanced communication and interactions on SMPs makes it necessary to integrate online social networks into the classroom in a more accessible way, thus enhancing the traditional learning environment [23, 29]. Mentoring in an online setting poses many difficulties even though online engagement offers different expected benefits. The potential interference of including SMPs in the classroom is one of the main issues [30]. Another study exhibited that over thirty percent of students failed to graduate with a STEM degree in four years of college [31]. A recent study showed that one of the most significant challenges faced by Universities was to keep the attraction of students in a particular course and their persistence [32].

Hence there is a need for an in-depth analysis that could accurately assess the degree of benefit or harm of SMPs based on communication patterns and assist educators in devising plans to utilize SMPs in a more advantageous manner. To make SMPs more valuable and accessible for students, instructors should learn more about how they impact students' learning and engagement to strategize the implementation of SMPs as a instructional instrument to merge them into classes [10]. Traditional datasets cannot adequately capture student communication strategies and analyze student interactions with such details and coverage. In contrast, social media datasets enriched with student activity information capture and identify students' perceptions of various STEM course topics to facilitate active learning [33]. User interactions on SMPs also facilitate the development of new user connections and networking opportunities which also associate with direct social impacts [10]. The use of networks can help analyze diverse, complex systems from natural, social, and technological domains [34]. Furthermore, they should give direction and help. Besides, educators can pay special attention to online discussions to ensure relevant ways to deal with courses and meet course objectives [35].

Various methodologies have yet to be determined to decide the issues encompassing social media as a tool for education and mentoring. Educators have committed to providing explicit assumptions and principles regarding using online distractions in the classroom to assist students in carefully using these tools. From the above literature, researchers explored the potential of social media data to solve various problems. Only a few studies investigated communication patterns related to EE and STEM in social media platforms within learning environments and educational engagement. This study’s goal of understanding the communication patterns of engineering students in an informal platform (X) will help leverage the institutions to strategize decisions on how to integrate the SMPs as a tool for diverse learning and enhancing knowledge retention, which is the critical contribution of this study.

Data and Methods

For our study, from the many SMPs we opted for X (Twitter) as our source of data. X is a practical education setting for engineering and STEM students, promoting concise communications, access to topic-issue professionals, and assembling participation via hashtags. Its benefits in higher education include experiential learning, rigid discussions, and

enhanced grades, pressing educators to investigate its functional importance for supporting notions and nurturing critical thinking.

SMP platform named X's Application Programming Interface (API) was used for data collection. Tweet data posted from January 2020 to December 2020 was extracted with intention to capture the communication pattern of EE. Data have been analyzed using the python programming language in order to identify the communication activities of different users regarding different aspects of engineering education. This data also captures the additional aspect of online EE as the timeline for dataset was during the pandemic spread of novel coronavirus (COVID-19) which increased the education through online mediums rapidly. Initial Extracted Data size was approximately with 110k tweets with 27 columns in the form of semi-structured text form. For data quality we reviewed the accuracy and uniqueness of the data by tokenizing relevant text data, making the data more accurate and precise for the topic and region set for the research. Availability of computational resources determined the selected Geo-location based search of social media data captures the topic related data making it comprehensive. Dataset was collected for the year of 2020 to complete dataset of X with unique tweets making the dataset complete. Research in the domain of SMP requires data with higher users' activity of a platform and that provides public access for researchers. For research of SMP data, it needs to be some platform that has previously deemed acceptable and performed by the previous studies. That is why for this research X was selected for data collection. Online education is growing rapidly, there's a need to identify the patterns of SMP data to integrate with the education reform for its benefits. Data is recent which will be helpful to identify yearly reporting of the trends, topics etc. in communication in SMPs. Data was then preprocessed and cleaned for analysis. It was then classified into user's socio-demographics with a pre-trained model [36]. As the extracted data was based on Geo-location the data was filtered with the main keywords ('Engineer', 'Stem', 'Education') relevant to this study. After the initial filtering the tweet text data containing the words resulted into the new dataset size was 3,605 tweets. Figure 1 shows the collected data description at different steps of data collection, preparation, and analysis. This data was then utilized to conduct network visualizations and analysis to obtain meaningful insights regarding student interactions.

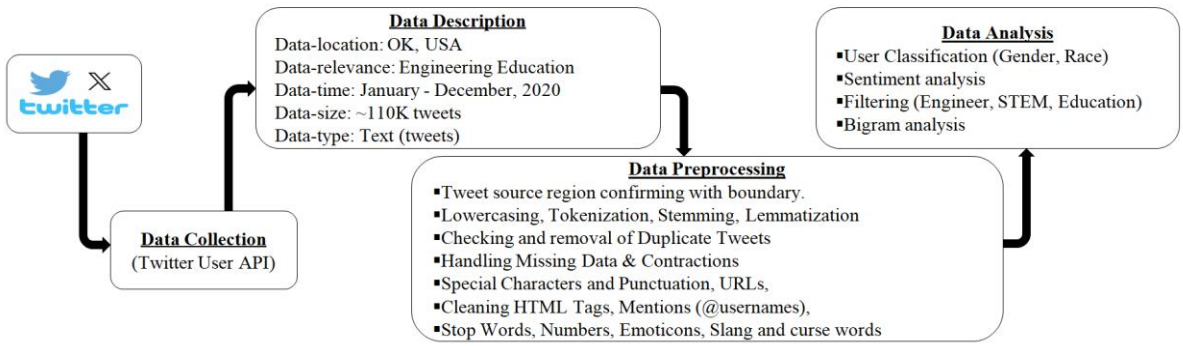

Figure 1: Framework for data collection, description, preprocessing and analysis.

Bigram Analysis:

Bigram analysis, a statistical model in natural language processing, calculates the likelihood of a word sequence by analyzing pairs of adjacent words; this approach assesses the probability of a word following its predecessor in a sentence [37]. This technique is crucial for textual data analysis, offering insights into the connections and cohesion between words.

Bigram analysis examines the semantic distance between word pairs, revealing the flow of concepts and the organization of ideas within the text [38]. Additionally, it identifies patterns and relationships between words, such as co-occurrence probabilities and connectivity [39]. This study performed bigram analysis to understand the patterns of educational communication within the context of EE in Oklahoma. Analyzing word pairings in social media posts, this study identified predominant themes discussed by social media users. A detailed explanation of the methodology and mathematical models underpinning bigram analysis can be found in the cited references [37, 40, 41].

Sentiment Analysis:

Sentiment analysis is another important tool for textual data analysis because it allows us to understand the emotions and opinions expressed within the text. It helps in identifying the general consensus and sentiment of the audience towards a particular topic or theme [42]. Understanding whether the sentiments are positive, negative, or neutral towards various aspects of EE can help identify areas of satisfaction or concern among students and faculty [43]. By analyzing changes in sentiment over time, emerging trends and shifts in opinions can be identified. This is particularly important in understanding how attitudes towards EE evolve, which can be crucial for making informed decisions about curriculum development and pedagogical approaches [44]. Moreover, this study extends the sentiment analysis by correlating average sentiment scores with geographical locations in Oklahoma. This geographical mapping helps uncover how perspectives and emotional responses towards EE differ across various regions. By highlighting these regional sentiment patterns and discrepancies, the study provides valuable guidance on where and how educational strategies might be adapted to meet local needs and preferences. To conduct this sentiment analysis, the study utilized the *VaderSentiment* Python package, which employs a lexicon-based approach to analyze sentiments [45].

User Classification (Gender, Race):

This study has used the gender-race (GR) model [36] which has been designed to predict gender and race using the first and last names of users. In its development, over 100,000 first names from the Social Security Administration (SSA) database and 160,000 surnames from the US Census Bureau were gathered and preprocessed. The model calculates letter occurrences in each name and uses this data to create an alphabet matrix enriched with race and gender labels. For race, names are categorized into Asian, Black, Hispanic, and White, and for gender, into Male or Female. This detailed process of feature engineering and systematic categorization enables the GR model to accurately predict gender and race based on names. The limitation of this model originates from its dependence on a limited range of racial categories and binary gender classification by their names. Gender is constrained to 'Male' or 'Female' due to data sourced from the SSA, excluding non-binary genders and a broader spectrum of racial identities. Future research should prioritize inclusive data collection representing diverse gender and racial identities for equity in engineering education.

Analysis and Results

Natural language processing requires thorough data preprocessing (text data in particular) with the available computational resources. In this section, the findings are discussed on a theme-based approach and their sentiment and overall polarity for the corresponding research

questions listed above (see Introduction and Motivation). The collected data was classified on a pre-trained gender identity and race/ethnicity model [36]. The model could classify only two genders (Male and Female), and for distribution of race/ethnicity into two categories: White and Others (Black, Asian, Hispanic, American Indian). This section below shows the findings for each sub-research question with their average sentiments of the tweets related to EE (n=3,605) with the most frequent topics. The data in Figure 2a) represents the racial distribution in tweets, and Figure 2b) represents the tweets' originating location map. Figure 2a) demonstrates that White individuals accounted for the majority (88.3%) of these tweets. Tweets from different racial categories were as follows: Asian (5.9%), Hispanic (5.3%), Black (0.3%), and American Indian (0.2%). It portrays that tweets in social media discussing EE have a very high racial disproportion.

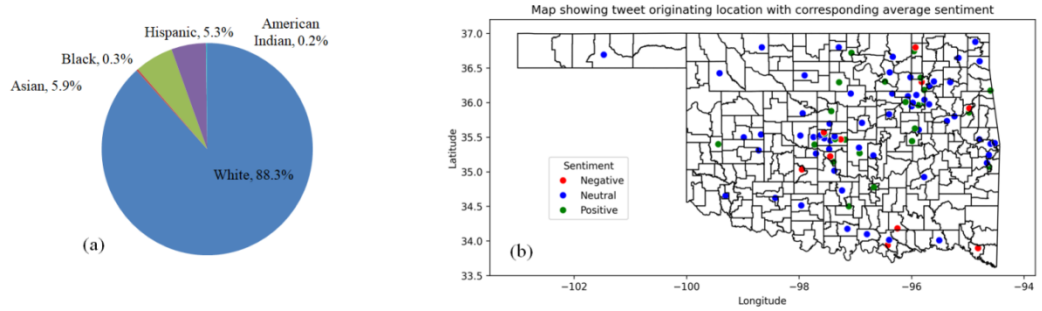

Figure 2: a) percentage of tweets by race and b) tweet location map with average sentiment (n=3,605)

*Please note in the tweet map the data points show the tweet originating location and if there were many tweets from same location the average sentiment is shown on the map.

A few sample tweets of this dataset are shared below and Table 7 in the appendix section contains selected tweet examples representing all sub-research questions.

- *'I'm extremely impressed with my OSU senior who works extremely hard at staying on top of his studies, priorities and challenges himself to excel in his future engineering career!'*
- *'We have to work on kids emotional health and troubleshooting more with them. They hate distance learning but I think is our lack of embracing this as a system than it actually being horrible. I have successfully taught and learned for 20 years.'*
- *'I'm not an economics major but I am a civil engineer. The EPA has strict measures for water quality. Often places have difficulty meeting these requirements or infrastructure is out of date causing issues. If money is low they often have to fix these issues through phase'*

Bigram Networks:

As discussed above, bigram analysis is a machine learning statistical model analyzing word pairs. From our dataset we have created two figures representing the network of the words. Figure 3 shows the plotted network for the top 100 bigram word pairs. In general, the word pairs in this analysis could be considered both as a topic or a theme. They become apparent in the analysis when it is talking more as a discrete topic in EE, or it is closely aligning with themes in EE. In this figure the web of words clearly visualizes how each word is connected with the other. It is based on how often the words appear together in a sentence. In this figure we can see some words in the center, like 'education' is the central node with the highest weight; it is connected with some words such as 'school' and 'system' in the second highest weighted nodes of the network, showing common patterns. Notable words that are connected to the central node education are: school, system, public, adult, center, higher, need, lack, health, board, special, department etc. This shows that the communication pattern for EE

relevant tweets talked about public education, adult education center, public school education system, education board, education needs and lack of education, among others. In addition if we look for the high frequent pair of the words outside this network, we can observe the notable pairs that was inside the EE communication patterns are ‘distance learning’, ‘software engineer’, ‘job opening’, ‘reeducation camp’, ‘systemic racism’, among others.

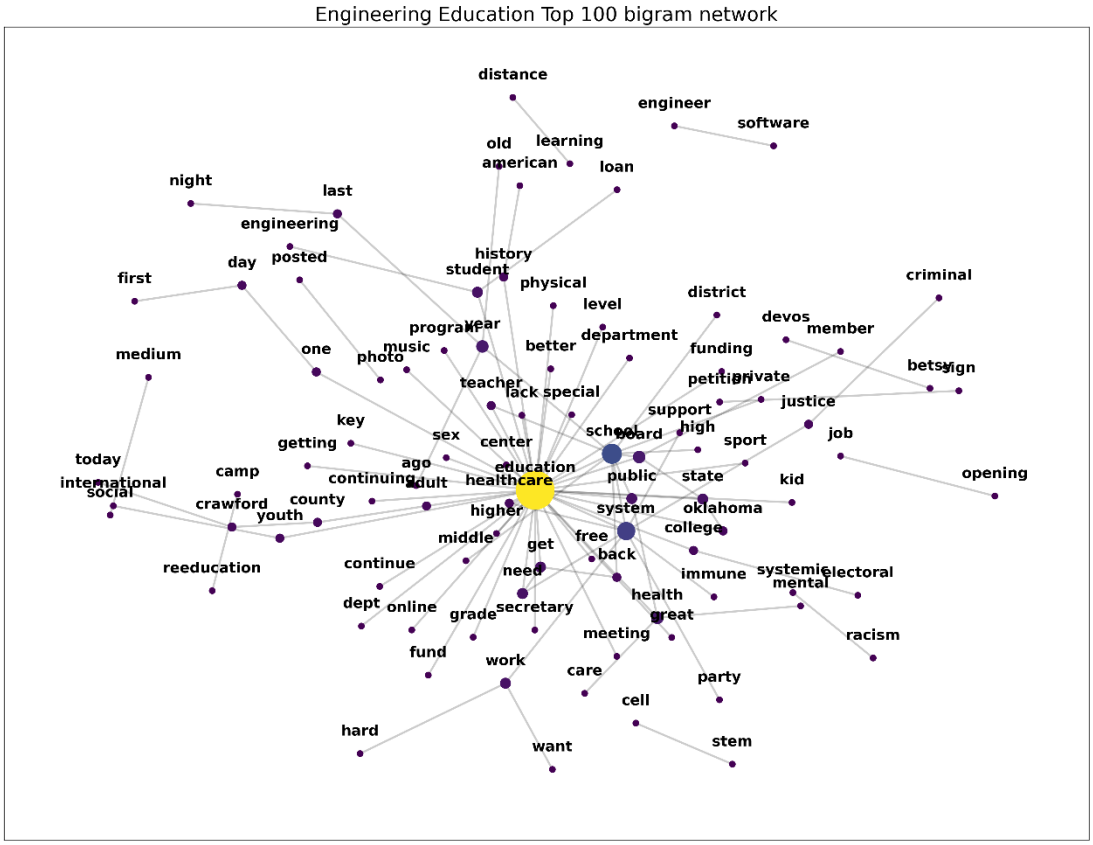

Figure 3: Top 100 bigrams of engineering education tweets

Figure 4 presents the top bigrams for each sub-research question category. In Figure 4a) the bigram network presents the disciplines in engineering connected in the network containing electrical, mechanical, chemical, biomedical, and industrial engineering along with engineering management, student, and major as the top bigrams in this category. It also revealed that the ‘civil engineer’ and ‘want work’ are two notable pairs outside the network but frequent in the communication pattern of EE. Figure 4b) presents the bigram network of engineering pathways where the central network consists of EE disciplines, science, technology, and classes. The pairs outside the network that were frequent in the communication were ‘senior spotlight’ and ‘little JavaScript.’

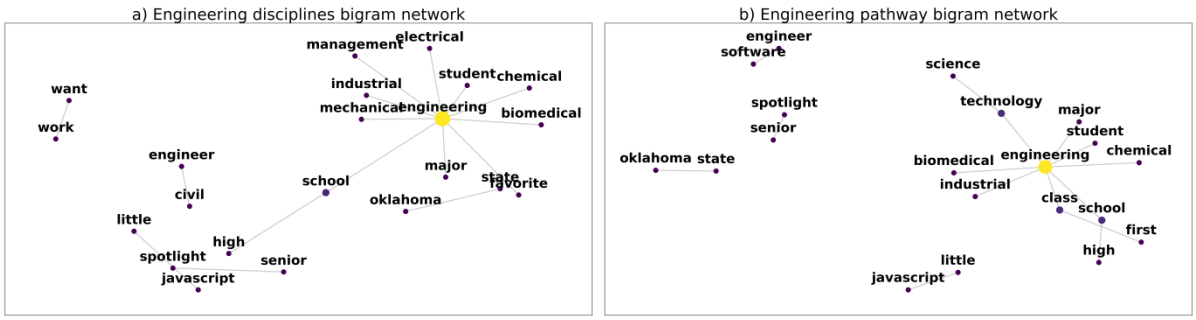

Figure 4: Top bigrams for each group a) engineering disciplines, and b) engineering pathway

Figure 4c) shows the network of communication patterns related to professions in EE. The network is mostly an interconnected network where communication discussing the professional STEM career, professional development, and professional engineering becomes the center of the network. Outside the network some important bigrams portray the word pairs such as ‘work skill’, ‘provide framework’, ‘social medium’, and ‘participate outreach’. Figure 4d) demonstrates the bigram network related to tweets discussion online EE, where it was observed that the education board in the central node connected with the words ‘distance learning’, and Oklahoma State’. There are also conversations about ‘plans to keep the school building closed’ in communication-related to the COVID-19 pandemic. Additional notable words would be ‘institutional care fund’. These discussions were about the courses becoming online and institute initiatives to cover the funds of the students who paid for campus courses yet become online due to the consequences of COVID-19.

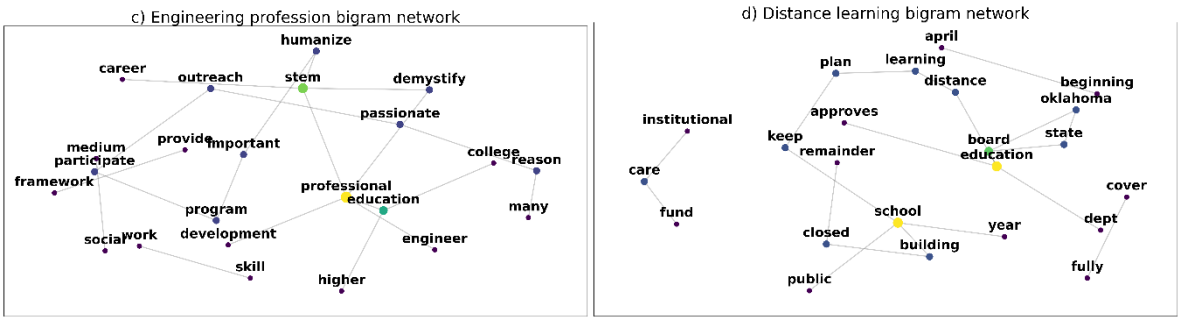

Figure 4: Top bigrams for each group c) engineering profession, and d) distance learning

Figure 4e) shows the communication pattern network related to diversity, equity, inclusion, and accessibility of marginalized and minor groups in EE. The network shows that the node education is connected with words such as access, women, Indian, and accessible. Some notable pairs outside the network related to EE discussions were: ‘STEM woman’, ‘need education’, ‘WereNIEA nativeeducation’, ‘systemic problem’, ‘Native American’, ‘womenwhocode, womenintech’ and ‘international student’. Here WereNIEA is a Twitter page of the Native Indian Education Association (NIEA), the top education supporter for American Indian, Alaska Native, and Native Hawaiian students. Figure 4f) displays the concern of student loans related to EE, where higher education and college education connect with student loans, debt, and added expenses of housing, cars, food, and devices (cellphones, computers).

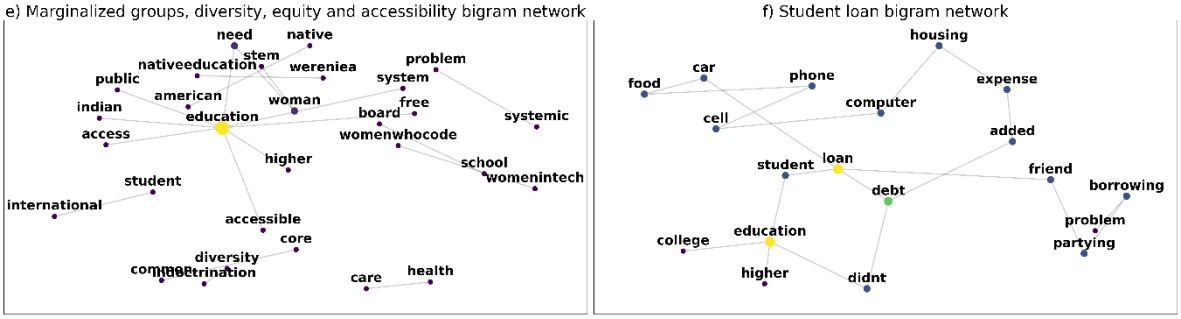

Figure 4: Top bigrams for each group e) marginalized groups, diversity, equity, accessibility, and f) student loan

In this section the 3,605 tweets are further filtered into six subcategories and analyzed in order to answer the sub-research questions.

**Please note that on the tables through 1-6 bigrams count mentioned are based on the occurrence in the set of tweets, which means there could be same pair of words occurring in same tweet more than once and vice-versa.

RQ1: *What are the primary concerns expressed through SMPs related to EE disciplines/majors?*

Table 1 presents sentiment analysis results for the set of tweets that are related to engineering disciplines. Sub-research question topic-specific filtering allowed us to analyze the 119 tweets that discussed majors and disciplines in engineering. The overall average sentiment in the tweets was positive, with a score of 0.38. The majority (79%) of these tweets were by White people, with a slight gender imbalance of 56% male and 44% female. Amongst these tweets, Biomedical engineering held the highest positive sentiment (average score= 0.7), while civil engineering exhibited a negative sentiment (average score= -0.14). Most engineering disciplines' tweets had positive sentiments, ranging from 0.3 to 0.7. This finding highlights a concern for electrical and civil engineering as it showed negative sentiments contrary to other disciplines. An in-depth analysis of these negative sentiment tweets showed concerns surrounding strict measures for infrastructure development by agencies and probable causal links for cancer. The tweets showed people's views about their professional activities, academic engagements, cultural dimensions, and community involvement in campus life and culture in engineering education.

Table 1. High-frequency word pairs and sentiments based on engineering education discipline.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
Engineering Major (*n*=119; average sentiment=0.378; 79%-White, 21%-Others; 56%-Male, 44%-Female)			
engineering, student	11	0.461	Positive
industrial, engineering	9	0.453	Positive
chemical, engineering	9	0.573	Positive
biomedical, engineering	7	0.703	Positive
engineering, major	6	0.301	Positive
mechanical, engineering	5	0.48	Positive
civil, engineer	4	-0.143	Negative
engineering, management	4	0.41	Positive
electrical, engineering	4	-0.01	Negative

RQ2: *How different social media actors interact and share opinions regarding engineering pathways?*

Communication patterns by social media actors (i.e., educators, students, institutes, alums, and industry professionals, among others) can provide various insights into the engagement of the actors in a network. Table 2 outlines sentiment analysis results for different areas of pathways in EE. Tweets selected for the analysis were in courses, topics, classrooms, and educational settings. The analysis mainly demonstrated positive sentiments for the word pairs. Tweets discussing Science, technology, engineering, and mathematics (STEM) showed relatively high positive sentiments. In contrast, the tweets presented a low positive sentiment score (around 0.2) discussing topics such as engineering class, engineering learning, engineering courses, and machine learning. This finding implies that tweets reveal positive sentiments for the STEM field in general; however, there is a concern that the sentiments for classes and courses for EE were low. These tweets originated from mainly White (83%) people, with a relatively balanced gender distribution. The analyzed tweets covered technology, education, diversity, job recommendations, and research. It showed concerns

about the quality of online education, gender dynamics in STEM fields, achievement in diverse representations, and the need for addressing societal issues related to employment, education, and housing. The tweets also highlighted the importance of hands-on projects, competitions in engineering education.

Table 2. High-frequency word pairs and sentiments based on engineering education pathways.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
Engineering pathways (*n*=133; average sentiment =0.373; 83%-White, 17%-Others; 52%-Male, 48%-Female)			
software, engineer	11	0.131	Positive
engineering, class	6	0.267	Positive
science, technology	5	0.781	Positive
technology, engineering	5	0.781	Positive
senior, spotlight	5	0.668	Positive
first, class	4	0.495	Positive
little, javascript	4	0.361	Positive
learning, engineer	3	0.12	Positive
science, engineering	3	0.523	Positive
engineering, math	3	0.695	Positive
machine, learning	3	0.12	Positive
engineering, course	2	0.122	Positive

RQ3: *How do social media user sentiments vary when they discuss about engineering profession?*

Table 3 reflects positive sentiments in discussions on professional education and development, with relatively high positive sentiments for themes such as ‘professional development’ (0.35) and ‘professional engineer’ (0.57). Also, the ‘STEM professional’ theme stood out with an exceptionally high positive sentiment score of 0.96. Overall, tweets consisted mainly of positive sentiments and discussed professional development and education, working skills, providing frameworks, and social media. The overall sentiment was positive in 46 tweets discussing the engineering profession, with an average sentiment score of 0.34. Of this set of tweets, significant contributors of these tweets were White (87%) and female (63%). The analyzed tweets emphasized community involvement, inclusive opportunities, and efficient inspiration for the students for STEM careers.

Table 3. High-frequency word pairs and sentiments based on engineering education profession.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
Engineering Profession (*n*=46; average sentiment=0.338; 87%-White, 13%- Others; 37%-Male, 63%-Female)			
education, professional	6	0.072	Positive
professional, development	3	0.35	Positive
professional, engineer	3	0.572	Positive
provide, framework	2	0.268	Positive
social, medium	2	0.275	Positive
skill, work	2	0.366	Positive
stem, professional	1	0.964	Positive

RQ4: *What are key concerns related to online EE and their corresponding polarity or sentiments?*

Table 4 shows positive sentiments in discussions about distance learning, education plans, and closed buildings, with ‘institutional care’ at 0.88. An in-depth analysis of the tweets

regarding institutional care showed the institute's initiatives to cover or refund the online education fees for students who have become online due to the COVID-19 pandemic. For 27 discussions of online education tweets, the average sentiment was primarily positive (average sentiment= 0.36). With a balanced gender distribution of tweets (56% female and 44% male), the primary contributors of these tweets were White (93%). The tweets expressed concerns about distance education in Oklahoma during the COVID-19 pandemic, focusing on policy directives, technology adaptation, student engagement, and equitable access to education.

Table 4. High-frequency word pairs and sentiments based on online engineering education.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
Online education (*n*=27; average sentiment=0.362; 93%-White, 7%- Others; 44%-Male, 56%-Female)			
distance, learning	20	0.218	Positive
board, education	8	0.169	Positive
learning, plan	6	0.296	Positive
building, closed	3	0.274	Positive
distance, education	3	0.795	Positive
public, school	2	0.201	Positive
institutional, care	2	0.882	Positive

RQ5: *Are there differences in public concerns and opinions expressed in SMPs when they discuss about marginalized groups, diversity, equity and accessibility?*

For underrepresented groups and minorities, Table 5a) summarizes sentiment analysis results for various discussion themes. The education system (-0.47) and public education (-0.24) themes exhibited predominantly negative sentiments. In contrast, discussions on diversity and inclusion, the secretary of education, and required diversity had more positive sentiments, with average scores ranging from 0.04 to 0.5. One of the tweets also captured very high negative sentiment on systemic racism. Tweet contributors were 91% White with a gender imbalance, 74% male and 26% female. The tweets cover diverse views on the role of diversity in education. Some argue against what they perceive as indoctrination through diversity initiatives and advocate for dismantling such programs alongside mainstream educational structures like Common Core. Others supported promoting diversity in education and fostering diverse perspectives in curriculum development and leadership.

Table 5b) highlights varied sentiments in discussions on different themes of women in EE. While topics like ‘woman, stem’, ‘systemic, problem’, and ‘black, woman’ convey positive sentiments with average scores ranging from 0.12 to 0.92, there are also themes such as ‘need, education’, ‘woman, need’, and ‘woman, education’ that reflect more negative sentiments, averaging between -0.15 and -0.37. Tweets reveal a pattern that there is a need for more women in education. Tweet contributors are mainly white (79%), with a balanced gender distribution of 45% male and 55% female. The tweets discuss gender equality, women's empowerment, education, technology, social issues, and mental health. They highlight challenges faced by women in different sectors, advocate for diversity in STEM fields, and criticize societal norms and inequalities.

Table 5c) portrays Tweets (*n*=31) centered on Native American themes revealed an overall positive sentiment (0.32). Most contributors identify as White (87%), with a significant predominance of females (81%). Positive sentiments represent discussions on essential topics such as Indian education, WereNIEA, native education, and department education. Conversely, negative sentiments emerge in conversations related to Native Americans, school boards, and indigenous students. The tweets focus on Indigenous education advocacy and

initiatives, including historical suffering, personal achievements, and community engagement to promote access to higher education and address systemic injustices.

Regarding accessibility, in Table 5d) tweets (*n*=41) displayed a positive overall sentiment (0.33). Most tweet contributors were White (83%), with a notable gender distribution of 71% female and 29% male. Key findings in sentiment analysis revealed negativity around topics such as educational and public access. In contrast, discussions about access to higher education and making education more accessible showed positive sentiments. The tweets emphasize the importance of accessible and fair education, student safety and mental well-being, inclusive education, and equal opportunities for marginalized communities. They also recognize the role of political leadership in addressing societal challenges like access to healthcare and reducing crime through investments in education and social welfare.

Table 5e) shows that the tweets (*n*=8) related to international students revealed an overall positive sentiment (0.38). The tweet contributors were mainly White (75%), with a notable gender distribution, with 63% female and 37% male. Findings showed positivity in discussions around international students, continuing education, and educational equity. The tweets emphasized the need for policies, institutional support, community engagement, and resources to support international students, particularly those who are first-generation.

Table 5. High-frequency word pairs and sentiments based on underrepresented and underserved groups in engineering education.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
a) Diversity & Inclusion (*n*=23; average sentiment=0.022; 91%-White, 9%-Others; 74%-Male, 26%-Female)			
education, system	4	-0.467	Negative
public, education	4	-0.235	Negative
diversity, inclusion	2	0.037	Positive
secretary, education	2	0.084	Positive
systemic, racism	1	-0.59	Negative
required, diversity	1	0.511	Positive
b) Women (*n*=73; average sentiment=0.163; 79%-White, 21%-Others; 45%-Male, 55%-Female)			
woman, stem	7	0.268	Positive
need, education	3	-0.152	Negative
systemic, problem	3	0.215	Positive
womenwhocode, womenintech	3	0.116	Positive
woman, need	3	-0.365	Negative
woman, education	2	-0.148	Negative
black, woman	2	0.398	Positive
learning, experience	2	0.56	Positive
free, education	2	0.92	Positive
c) Native American (*n*=31; average sentiment=0.315; 87%-White, 13%-Others; 19%-Male, 81%-Female)			
indian, education	7	0.317	Positive
wereniea, nativeeducation	4	0.235	Positive
native, American	3	-0.181	Negative
department, education	2	0.7	Positive
school, board	2	-0.148	Negative
education, program	2	0.472	Positive
indigenous, student	1	-0.361	Negative
d) Accessibility (*n*=41; average sentiment=0.328; 83%-White, 17%- Others; 29%-Male, 71%-Female)			
access, education	7	-0.019	Negative
higher, education	4	0.195	Positive
education, accessible	3	0.384	Positive

people, access	2	0.683	Positive
access, public	2	-0.293	Negative
e) International students (*n*=8; average sentiment=0.382; 75%-White, 25%- Others; 37%-Male, 63%-Female)			
international, student	7	0.357	Positive
student, country	2	0.292	Positive
continue, education	2	0.55	Positive
educational, equity	1	0.912	Positive

RQ6: *Do social media users express negative emotions while they discuss student debts and loans?*

Identifying a potential concern (loan) for EE students, we analyzed 20 tweets. The average sentiment was mainly low positive (avg. sentiment= 0.19). 90% of tweet contributors were White, with a balanced gender distribution. Key themes include low positive sentiments about ‘student loans’ (avg. sentiment= 0.12) and negative sentiments about ‘loan debt’ (avg. sentiment= -0.04). The tweets highlight financial challenges in higher education, including student loan burdens, rising costs, and their economic impact. They also showed the diverse views on addressing education expenses, student loan forgiveness and the government's role in financing education.

Table 6. High-frequency word pairs and sentiments based on engineering education loan/debts.

Topic/Theme	Count	Avg. Sentiment	Overall Polarity
Student loan (*n*=20; average sentiment =0.191; 90%-White, 10%- Others; 50%-Male, 50%-Female)			
student, loan	15	0.12	Positive
loan, debt	6	-0.039	Negative
education, student	2	0.036	Positive
added, expense	1	-0.09	Negative

Discussions:

Studies have shown that the use of social media as a learning environment can have a positive impact on student engagement and learning outcomes. For example, a study [46] by found that students who used social media as a learning environment reported higher levels of engagement and satisfaction with their courses compared to those who did not use the platform. In addition, research by [47] found that students who used SMP (Facebook) as a learning environment scored higher on assessments compared to those who did not use the platform.

In this comprehensive sentiment analysis of social media posts related to engineering education (EE), the study uncovers a diverse range of sentiments and concerns across different aspects. Regarding the primary concerns in EE disciplines and majors (RQ1), the analysis shows biomedical engineering as highly positive, whereas civil engineering is seen negatively. Overall, the sentiment in engineering disciplines is predominantly positive. When examining how social media actors interact and share opinions about engineering pathways (RQ2), the findings reveal a general positivity across various themes, especially in software engineering and technology-related discussions. The study also explores variations in sentiments about the engineering profession (RQ3), finding a majority of positive sentiments in discussions about professional education and development, with some themes like "professional, engineer" receiving particularly high positive scores. In terms of concerns related to online EE (RQ4), discussions exhibit positive sentiments, especially around institutional care and distance learning.

A significant part of the study focuses on public concerns about marginalized groups (RQ5). The sentiments here are varied, with negative sentiments noted in discussions about the education system for underrepresented groups. In contrast, discussions around diversity and inclusion show more positive sentiments. Lastly, the analysis of sentiments on student debts and loans (RQ6) indicates a generally positive sentiment, although there are some negative sentiments associated with loan debts. Throughout the study, the majority of social media contributors are identified as White, with varying gender distributions in different categories. Overall, the sentiment analysis shows a picture of predominantly optimistic attitudes towards various aspects of engineering education, alongside highlighting concerns in specific areas like civil engineering and education for marginalized groups.

Conclusions, Key Findings, and Limitations:

The analysis delves into natural language processing for engineering education tweets. The dataset, filtered for engineering education themes, is then classified based on a pre-trained model for gender and race, distinguishing between two genders (Male and Female) and two racial categories (White and Others). The racial distribution in the data reveals White individuals as the majority at 88.3%, with themes explored in different segments of engineering education communication. Further exploration, through research questions, unveils sentiments across engineering disciplines, with biomedical engineering being notably positive, and discussions about online education displaying an overall positive sentiment.

Tables 1-6 highlight sentiment analysis across various themes, encompassing professional education, software engineering, and discussions on accessibility. Notable findings include high positive sentiments in professional education and technology-related themes, as well as positive sentiments in discussions about distance learning. The high positive sentiments in professional education and technology-related themes could be indicative of a generally optimistic outlook within these fields, possibly driven by the prospects of career growth and advancements in technology. In addition, due to advancement in technology many individuals view distance learning mode of education favorably, possibly due to its convenience and accessibility, especially in light of recent changes in education delivery methods. The racial distribution in tweets discussing underrepresented groups and minorities reflects varied sentiments, with negative tones in education system discussions and positive sentiments in diversity and inclusion topics. Negative tones in education system discussions could stem from concerns about disparities and challenges faced by these groups within the educational system, while positive sentiments in diversity and inclusion topics may reflect a recognition of the importance of promoting inclusivity and equity. Themes related to women and minorities also showcase a mix of positive and negative sentiments. This could be indicative of ongoing debates and discussions surrounding these issues, where both positive and negative perspectives are expressed. Overall, these patterns may be the result of the diverse and evolving nature of the subjects being analyzed.

Specifically, discussions on Native American themes highlight mostly positive sentiments, while accessibility discussions present both positive and negative aspects. International student discussions lean towards positive sentiments, emphasizing the importance of continuing education and promoting educational equity. Lastly, student loans data analysis reveals a primarily positive sentiment, with key themes focusing on ‘student loans’ and touching on negative sentiments related to ‘loan, debt.’ The gender distribution across these discussions varies but often leans towards a balanced representation, reflecting the diverse

voices and perspectives contributing to these important conversations. Overall, this sentiment analysis provides a nuanced understanding of the multifaceted nature of these topics and their significance in contemporary discourse.

The gender-race model has certain limitations, particularly in its ability to represent a diverse range of genders and races. The gender model is constrained by the binary classification of gender into 'Male' or 'Female', as the training data was sourced from the Social Security Administration, which only recognizes these two categories. This limitation excludes non-binary, genderqueer, and other gender identities that do not fit into the traditional male-female dichotomy. Similarly, the race model is limited to four categories: Asian, Black, Hispanic, and White. This classification is based on data from the US Census Bureau, which only reported these specific racial categories. As a result, the model may not accurately represent the full spectrum of racial identities, particularly those that are multi-racial or do not fit neatly into one of the four listed categories. These limitations highlight the need for more inclusive data collection practices to better reflect the diversity of gender and racial identities in society.

In this study, we performed a comprehensive analysis of data for the year 2020, and future research endeavors will extend our examination to subsequent years to reveal evolving trends and patterns of this communication. Future research should also consider designing more inclusive models for gender and race by analyzing alternative data sources encompassing a more comprehensive range of gender identities and racial classifications for equity in engineering education.

Appendix

Table 7: Sample tweets from the dataset

Example Tweets (Corresponding sentiment scores provided in parenthesis):
I lost my original interest in pursuing a career in computer science & Engineering that I gained when I was four. So I gained interest in Digital Media during my high school years. I'm now 27 with an AAS in Digital Media Design, studying to get a certification in networking (0.943)
I´m not an economics major but I am a civil engineer. The EPA has strict measures for water quality. Often places have difficulty meeting these requirements or infrastructure is out of date causing issues. If money is low they often have to fix these issues through phases (-0.6956)
I´m extremely impressed with my OSU senior who works extremely hard at staying on top of his studies, priorities and challenges himself to excel in his future engineering career! (0.7783)
A fun thing I learned from knocking on doors for ----: throughout the 30s, OU law and engineering students had a bitter rivalry that included pranks, stealing mascots, and vandalizing statutes. I think we should bring this back so I can give those nerds some swirlies. (-0.4939)
This is one of the many reasons that I am so passionate about outreach and participate in programs like LettersPreSci and SkypeScientist. It´s so important to humanize STEM professionals and demystify STEM career paths so that we can excite and inspire students, not scare them. (0.9639)
Many low-wage workers particularly Black, Latino or Hispanic, and Indigenous workers are trapped in multigenerational lower-caste jobs without access to career exposure, premium education, or professional networks. (-0.7717)
Distance learning starts today: Today is the deadline the OK Dept. of Education gave districts to put a distance learning plan in place. Links to all the continuous learning pages for the major districts. (0.4466)
We have to work on kids emotional health and troubleshooting more with them. They hate distance learning but I think is our lack of embracing this as a system than it actually being horrible. I have successfully taught and learned for 20 years. (-0.6249)
Wow. There is so much in here to unpack. Thank you for sending along. I moved from a female dominated industry (education) to finance and it has been a continual learning experience of advocacy for myself and other women. The sample sentences here are so helpful thank you. (0.9169)
Popping in to give a shout out to all of the wonderful, incredibly talented, hard-working, inspiring and world-changing #WomenInSTEM on this #InternationalWomensDay. (0.9045)

Women need education, and to be taught that there is more to life than laying on your back & popping out babies. Women need to be taught that submission is not a virtue. We do not need women like you filling our heads with performative nonsense. (-0.7304)
16 days to pledge! More intentional and inclusive plan. The stats on minority women in #STEM is staggering. I will include a #HowTo find *your* path to STEM. Forget bootstraps. Wherever you are, this book will meet you halfway. #ChangeTheSystem #women (-0.2263)
I really LOVE my students, I love cheering them on, I love creating access, I love being their support system, I love the community we build (0.9827)
We also have to consider the additional burden that students are experiencing - access to technology, internet connectivity, new location to learn/study, public transportation systems... these challenges are not shared equally across the country and socioeconomic groups (-0.5627)
Oklahoma has 39 sovereign nations within its borders, and our native tribes are our greatest strength, our finest champions for healthcare and education for all Oklahomans, not just members of their tribes. I am grateful to them, and the impact they have on our culture heritage (0.93)
Just now asking. He's never been to any of the bad Native American reservations. Not all are bad but those that are more about preservation of the way they are, are bad. Poor diet, hardly any education, hardly any way out. Yes, in America, and for decades. (-0.7701)
If you have ideas for ways that computer-aided chemE education can better foster diverse perspectives and URM engagement in computing research, I'm happy to listen. We also have some task forces. Recommended voices that need to be included? (0.886)
It is time to rethink higher education, it is destroying the fabric of our society, it suppresses free thought and stifles the diversity of opinions that our nation was founded upon. We must tear down these institutions and fundamentally restructure all aspects from the bottom up. (-0.0772)
International students, you can continue your education! OC is prepared for in-person classes for fall 2020, and we can help you transfer. Students from more than 50 countries make OC home. #internationalstudents #studentban (0.5574)
A college education was transformational for me as a #firstgen student. It changed the trajectory of my life and opened doors to international travel, purpose, and understanding my purpose. (0)
I love education. I am fortunate enough to have gotten 3/4 fully paid for. 1/4 is filled with payment plans and loans. I just wish it was more affordable //: AND THERE WERENT SO MANY RIDICULOUS, RANDOM FEES (0.9213)
Cancelling student loans will only further enable financial illiteracy and further incentivize educational institutions to continue raising their costs. #studentloans #debt (-0.7351)

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