Assessing Twitter's (X) Influence on Scientific Engagement and Saudi Women's Empowerment: A Mixed-Methods Study

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تقييم تأثير تويتر (X) على المشاركة العلمية وتمكين المرأة السعودية: دراسة مختلطة

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ملخص:

تبحث هذه الدراسة في استخدام تويتر كأداة للمشاركة العلمية بين النساء العربيات، وخاصة في المملكة العربية السعودية، وهو موضوع مثير للاهتمام يبرز إمكانات وسائل التواصل الاجتماعي في تمكين المرأة في مجال العلوم والتعليم. استخدمت هذه الدراسة نهجًا منهجيًا مختلطًا لتحديد تصور المرأة السعودية لاستخدام تويتر كأداة للمشاركة العلمية ودوره في تمكين المرأة السعودية. لذلك، قامت هذه الدراسة بالتعاون مع النساء السعوديات اللاتي لديهن حسابات على تويتر. لأغراض التحليل النوعي، أجريت مقابلات وجهاً لوجه مع ٢٠ امرأة سعودية، ولأغراض التحليل الكمي، تم توزيع الاستبيان الذاتي على ٤٠٠ امرأة سعودية. أظهرت نتائج الدراسة أن تويتر أثر بشكل إيجابي على النتائج التعليمية للطلاب والتعلم الجماعي بسبب أنشطتهم المتكاملة على تويتر ومشاركتهم في المناقشات عبر الإنترنت. علاوة على ذلك، تتمتع النساء السعوديات بحرية التعبير التي يوفرها تويتر حيث يمكنهن التعبير عن آرائهن المستنيرة المتعلقة بدراساتهم المحددة.

الكلمات المفتاحية: المشاركة العلمية، تمكين المرأة، أداة التعلم، تويتر، وسائل التواصل الاجتماعي، حرية التعبير

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Abstract: This study examines the use of Twitter as a tool for scientific engagement among Arab women, specifically in Saudi Arabia, which is an intriguing topic that showcases the potential of social media in empowering women in the realm of science and education. Furthermore, this study employed a mixed methodological approach to determine the perception of Saudi women towards the use of Twitter as a tool for scientific engagement and its role in empowering Saudi women. Further, this study recruited Saudi women who have accounts on Twitter. For qualitative analysis, face-to-face interviews with 20 Saudi women were conducted, and for quantitative analysis, the self-administered questionnaire was distributed to 400 Saudi women. The study results showed that Twitter has positively influenced students' educational outcomes and collective learning due to their integral activities on Twitter and their involvement in online discussions. Moreover, Saudi women enjoy the freedom of speech offered by Twitter as they can express their knowledgeable opinions related to their specific courses.

Keywords: Scientific Engagement, women empowerment, learning tool, Twitter, Social media, freedom of speech

1. **Introduction**

Social media technology has altered the methods of interaction between people on a day-to-day basis. Social media is the fastest-expanding digital technology comprising mobile-based and web-based applications that permit users to interact, communicate, and share information in a digital environment (Diug et al., 2016). Social media networks have been used extensively for searching, storing, discovering, learning, and sharing knowledge; thus, they are considered effective drivers for social learning. Most people, especially the young generation, believe that traditional platforms for communication, such as Emails, are too official; preferably, they adopt more strong channels that provide instant feedback. Therefore, cyberspaces provide modern science communications methods that bolster collaborative teaching and social learning (Lopez-Goni & Sanchez-Angulo, 2018).

As of 2025, Twitter (now X) has approximately 550 million active users worldwide (Global Media.

Insight, 2025). It integrates the service of microblogging that permits the sharing of short messages, which include videos, hyperlinks to other sites, and images. Twitter intended to spread, generate, and exchange brief statements, making it the most efficient, quick, and collaborative platform to share information. Once the information is shared on Twitter, it serves as an international publication originating from the user is free, is online, and constantly updates information (Lopez-Goni & Sanchez-Angulo, 2018). Because of these reasons, Twitter emerged as an imperative platform for a group of scientific stakeholders to communicate with each other. In addition, numerous research centers and scientific societies use Twitter to market their upcoming conferences and journal publications and promote blogs and science reports (Ferguson & Medford, 2020).

Saudi Arabia is a culturally, traditionally, and religiously conservative country. However, dynamics have completely changed in Saudi Arabia because of the influence of social networking sites, and Saudi Arabia has experienced exponential growth in social media. As per the report of KSA Social Media Statistics 2025, the total population of Saudi Arabia in 2025 was 37.99 million, and the active social media users totaled 78.45% (29.80 million) of the population (Global Media Insight, 2025). Twitter is the third most popular social media platform after Facebook and Instagram. On average, Saudi spends 3 hours and 2mins daily on social media

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through any device. Specifically, Twitter has 24.94 million active users. Active Saudi users integrate 68.7% of the total number of users on social media platforms. Moreover, the percentage of Saudi women using Twitter has risen from 30% in 2020 to 34.2% in 2023 (Global Media Insight, 2025). In 2025, the female population of Saudi Arabia is estimated to be around 39.3% of the total population. This marks a slight increase compared to previous years (Global Media Insight, 2025).

Advanced technology and effective information sharing enable women users to confidently express their challenges and issues. Twitter offers women an innovative method to interact and communicate by enhancing their abilities and knowledge in women. Women's empowerment is integrated into females' perceptions, opinions, and viewpoints on several concerns related to society and culture that facilitate raising their social and current status (Gangwani et al., 2021). Mourtada and Salem (2011) demonstrated through their research that social media helps women gain empowerment by allowing better promotion of women's rights better employment opportunities and increased personal expression.

Moreover, Twitter potentially has the power to transform the interaction between society and science. Students can use Twitter to expand their network with community leaders, gain information related to science and technology from the classrooms, and motivate fellows to select science as a career. Scientific engagement is defined as the involvement of students in science and science-related activities, as well as their attitudes and interest in science. In Saudi Arabia, women remarkably make their careers in science and science-related fields, representing 58% of university students who study science, engineering, mathematics, technology, physics, and statistics (Arab News, 2023). Thus, Saudi women enthusiastically pursue their careers in the STEM field provided by their universities. Therefore, the study aims to explore how Twitter played its role as a tool for scientific engagement among Arab women, specifically in Riyadh, Saudi Arabia. In addition, this study also examines how Twitter motivates Saudi women to engage in several economic and social issues to stimulate the procedures for women's empowerment in Saudi Arabia. This study contributed to the existing literature by exploring the perception of female students towards Twitter as a learning tool in science and education. The conception of

empowerment is multifaceted, encompassing economic, social, political, and educational dimensions. Aimed at the devotion of this study, knowledgeable empowerment is the focus, which refers to the acquisition of knowledge, critical thinking skills, and the ability to make informed decisions. This type of empowerment enables Saudi women to expand their academic engagement, improve self-confidence in expressing opinions, and increase participation in STEM fields (Mueller et al., 2021). Thus, it is an intriguing topic that showcases the potential of social media to empower women in science and education. Based on the study's objective, we postulate the following research questions.

Q1. How do Saudi women perceive and use Twitter for their educational learning?

Q2. What is the impression of Twitter in empowering female students in Saudi Arabia?

2. Literature review

Academic social media adoption has built modern scientific engagement platforms, especially for women enrolled in STEM fields. Twitter (now known as X) operates as a core platform that supports scientific networking together with knowledge spread while fighting for equal opportunities across genders. A recent review investigates the current scientific research from 2025 about the role of Twitter as a platform for women's scientific engagement through the evaluation of advantages and obstacles with suggested enhancements.

The Theoretical Framework of this study is based on two key theories: Social Learning Theory and Empowerment Theory, which suggest a robust lens for consideration of how Twitter encourages Saudi women's scientific engagement and empowerment. Social Learning Theory (Bandura, 1977) enlightens that individuals obtain information and assistance not just by concluded individual understanding, but also by witnessing and networking with others within their social surroundings. Twitter encompasses this philosophy by contributing a real-time platform where Saudi women can participate in scientific deliberations, work together with peers, and access mentorship from professionals across the globe. Concluding this interface, women can perceive and contribute to theoretical dialogue, thereby improving their learning experience. The platform enables them to learn through both formal and informal interactions, if a dynamic space for acquaintance conversation, which spreads elsewhere traditional classroom backgrounds.

Empowerment Theory (Kabeer, 1999) highlights that authorization is a process containing access to resources, the enlargement of agency, and accomplishing meaningful significance that grants. In the context of this study, Twitter empowers Saudi women by proposing assets for learning and self-expression, increasing their sense of organization, and promoting outcomes such as amplified self-assurance, participation in professional networks, and greater freedom to voice opinions. Women can admittance scientific knowledge, involved in academic debates, and feel empowered to express their views on societal issues, all of which subsidize their instructive and personal growth.

2.1. Enhancing Visibility and Professional Networking

Through Twitter women scientists can expand their research visibility which enables them to build connections with researchers throughout the world. The available platform provides users access to academic discussions while they can promote their work with hashtags including #WomenInSTEM and #AcademicTwitter which expands their recognition beyond conventional publishing channels. Women scientists obtain increased research citations and academic collaborations through regular participation on Twitter beyond traditional networking practices. Twitter serves as an unofficial mentoring environment that enables beginning women scientists to both receive guidance and discover professional mentors as well as address their career development concerns. Membership in established online communities along with scientist-networking enables women to find a sense of belonging which helps them continue in male-dominated fields. According to Van Noorden (2014), women used to receive lower exposure within scientific discussions. Through Twitter publication, women scientists have direct channels to disseminate their work which eliminates barriers found in academic publishing gateways. Research analysis on Twitter during 2025 demonstrated effective promotion techniques lead women-led studies to receive high engagement numbers which decreases gender disparities in scientific communication.

2.2. Encouraging Institutional Support

Research institutions and universities play an essential role in determining the next generation of scientists, and they must communicate their member's effective science communication methods that influence social media platforms such as Twitter.

digital age, scientific dissertation increasingly happens online, and organizations must equip students, principally female scientists, with the crucial tools and strategies to subsidize effectually in these spaces. Specifically, women scientists need to be provided with tailored Twitter training programs that can enhance their ability to engage in academic dialogues, promote their research, and build professional networks. Such programs would empower female scientists to use Twitter strategically to communicate their work, connect with peers, and gain visibility in their respective fields (Li et al., 2021). Additionally, social media networks like Twitter have predicted the challenges of online harassment and discrimination, which excessively affect women and understated groups. To report these encounters, platforms have instigated systems directed at harassing online bullying and gender-specific intolerance. However, though these systems have smoothed to some extent, it remains critical for scientific communities to develop specific guidelines and procedures to address destructive relations in a way that confirms safer women to ensure that women can engage in scientific dialogues without the fear of harassment or discrimination, ultimately fostering a more equitable academic environment (Veenstra & Huitsing, 2021).

2.3. Leveraging AI for Fairer Engagement

AI-based technological solutions will help tackle algorithmic bias while promoting equal visibility for scientific content from underrepresented authors. Enhanced personalized analytics methods serve to assist women scientists in their Twitter engagement optimization. Through AI systems scientists can detect and fix engagements that do not provide sufficient visibility for female scientists. Machine learning systems accept training to enhance role condition controls which support the promotion of content from various minority populations. AI technological capabilities provide women scientists with optimized engagement analytics tools that enable them to enhance their Twitter performance by finding peak posting times and proposing popular hashtags while monitoring audience reactions. Through this process, scientists can enhance their communication approaches to achieve the greatest results from their scientific outreach activities (Faus et al., 2025).

Through AI technology women scientists can combat the widespread issue of harassment that they experience on social media platforms. Natural language processing technology at an advanced level enables instant toxic comment detection which automatically

produces alerts or filters out these abusive comments (Pan et al., 2024). The AI-based moderation system enables researchers to block selected users or mute specific comments while minimizing harassment stress so that scientific discussions remain productive. The promising benefits of artificial intelligence require ethical considerations to prevent excessive content filtering or censorship. AI tools should be devised through collaborative work between developers researchers and women scientists to fulfill their specific requirements and reactions. The combination of AI systems designed for fairness in algorithms together with content optimization methods and digital safety measures allows Twitter to provide a platform where women scientists can thrive without exclusion (Faus et al., 2025).

Empowerment represents a complex idea that scholars examine throughout linguistics terminology along with procedural analysis. From a linguistic standpoint "empowerment" now represents a spectrum of different empowerment areas including both economic and social political and educational fields. Within this research cognitive empowerment serves as the main emphasis since it includes acquiring knowledge together with mastery of critical thinking and the capability to make evidence-based decisions. Empowerment means changes based on cultural backgrounds and academic fields as seen by linguistic research which also determines how authorities implement it through their programs (Assaf, 2024). The accurate terminology definition of cognitive empowerment needs clarity because it separates itself from additional empowerment types. Cognitive empowerment develops individuals' mental abilities by teaching them about themselves while granting them the independence to make their own decisions.

2.4. Research Hypotheses

Science-related social media engagement together with its effects on female empowerment remains a focus of recent research investigations (Miralam et al., 2025). Research done by Al-Shammari et al. (2023) showed that Middle Eastern female university students became more interested in academic exploration through their real-time expert interactions on Twitter (X). Hassan and Ahmed (2024) revealed that Saudi female professionals use Twitter as a tool to create professional networks which leads to career growth. Therefore, the present study focuses on Saudi female

university students in Riyadh, specifically at Princess Nourah Bint Abdulrahman University, within the time frame of 2025. The research analyzes Saudi females' Twitter interaction to assess its connection with empowerment through these provided hypotheses:

H_1: There is a positive relationship between Saudi women's involvement in Twitter and their educational awareness.

H_2: There is a positive relationship between Saudi women's involvement in Twitter and their empowerment across various aspects (e.g., decision-making, confidence, leadership).

H_3: There is a positive relationship between Saudi women's involvement in Twitter and their social interaction and networking.

H_4: There is a positive relationship between Saudi women's involvement in Twitter and their economic opportunities and financial independence.

3. Methodology

3.1. Study Design & Setting

The research method used a combination of qualitative and quantitative techniques to study how Saudi women use Twitter for scientific engagement and empowerment in scientific and educational fields. A mixed methods research design is comprised of both qualitative and quantitative approaches. This research took place at Princess Nourah Bint Abdulrahman University, Riyadh, with a population of 27,888 female students, and this university facilitates both graduate and undergraduate studies. It is a comprehensive university for women and is well-known for its education and scientific research initiatives. This study was approved by the Institutional Review Board of XXXX, University; approval number XXXX.

3.2. Population & Sample Size

A considered population size for this study is 27,888 female graduate and undergraduate students in the university Princess Nourah Bint Abdulrahman. This study used purposive sampling methods to achieve the aim of the research. The reason behind adopting the purposive sample is that this sampling method allows the selection of the participants who probably have adequate and helpful information related to the subject of the study. The sample size for quantitative analysis comprised 400 females with a response rate of 61%. Then, respondents were purposively sampled for face-to-face interviews from the initial sample. The characteristics of the sample are summarized in Table 1.

Table 1: Characteristics of the Study Sample

Demographic characteristics	Frequency	Percentage
Age		
< 25 yrs.	35	8.8
26-30 yrs.	241	60.3
30-35 yrs.	124	31.0
Education		
Undergraduate	180	45.0
Graduate	220	55.0
Nationality		
Saudi Arab	371	92.8
Other	29	7.2
How long have you been on Twitter?		
6 months	18	4.5
1-2 yrs.	23	5.8
3-5 yrs.	67	16.8
More than 5 yrs.	292	73.0
How many hours/day do you spend on Twitter?		
Less than 1 hour/day	32	8.0
2-3 hours /day	294	73.5
More than 5 hours/day	74	18.5
Less than 1 hour/day	32	8.0

3.3. Study Tool

For quantitative analysis, the cross-sectional survey has been constructed after reviewing extensive studies of the existing literature (Beena, 2012; Sudiran, 2016; Deaves et al., 2019; Alyami, 2021). Further, the questionnaire was constructed based on a 5-point Likert scale. The questionnaire incorporated two sections. The first section included 5 items to examine the use of Twitter as a scientific engagement tool, and the second section included 7 items to highlight the role of Twitter in empowering Saudi women (Akpuokwe et al., 2024).

For qualitative analysis, the data was collected through face-to-face interviews of 20 Saudi females, purposively sampled from the initial sample. The interview was based on the 10 open-ended

questions to express their opinions and thoughts about how Twitter plays an important role in their education, specifically related to science subjects, and how Twitter empowers them to express their perception confidently in an open platform (Almalki, 2025).

3.4. Data Collection

The study employed a self-administered questionnaire based on the 5-point Likert scale: (1) strongly agree, (2) agree, (3) undecided, (4) disagree, (5) strongly disagree. The constructs for analyzing the use of Twitter as a tool for scientific engagement have been developed by reviewing the past studies of Sudiran (2016) and Deaves et al. (2019), while the constructs for examining the role of Twitter in empowering Saudi women have been constructed after reviewing the studies of Beena 2012; Alyami,2021. An online questionnaire was distributed to female students through the Google Forms platform, and their email addresses were collected through their Twitter accounts. The targeted population for this study was 27,888 female graduate and undergraduate students. However, the minimum recommended sample size by Raosoft software was 379 female students with a 5% margin of acceptable error and a 95% confidence interval. Therefore, employing an online cross-sectional survey of at least 379 female students is necessary to collect the quantitative data. Thus, we distributed 650 questionnaires to respondents through their email addresses, and they were requested to return the questionnaire within two weeks. However, we received 400 questionnaires with complete information. So, we conducted this research on the responses of 400 respondents to avoid response bias, and the study's response rate was 61%.

3.5. Interviews

The qualitative part of this study involved semi-structured face-to-face interviews with 20 Saudi female students selected through purposive sampling. The researcher selected semi-structured interviews because this type enables deep exploration of participants' experiences while keeping important topics uniform. The interview questions derived from Aladsani (2018) and Alyami (2021) focused on understanding participants' views about Twitter as an engagement platform for science and empowerment. Constructing 10 open-ended questions to understand the perceptions of Saudi women towards the use of Twitter as a scientific engagement tool and its role in empowering them more comprehensively.

During the research process, several challenges were encountered. Firstly, scheduling conflicts made arranging interviews

with some participants difficult, as they had academic and personal commitments. Several participants first showed reluctance to share their opinions because they feared that their privacy could be compromised while their answers could be misused. I addressed participant concerns about privacy by obtaining informed consent and then confirming that all participants would stay anonymous. Technical issues related to unsteady Internet connections became a problem for conducting online interviews because face-to-face meetings were prevented by these technical limitations. Although several obstacles existed the research collected detailed qualitative information to support the quantitative data findings.

3.6. Reliability & Validity

For the face validity of the questionnaire, it is presented to a bunch of experts in different Saudi universities, who are asked to give their valuable opinions on every construct so the appropriateness of the construct, linguistic formulation, and comprehensiveness of the questionnaire are ensured. After the expert's opinion, some modifications were made by removing two constructs. The Cronbach Alpha has been used to compute the reliability of the questionnaire and was applied to a pilot study. The overall reliability of the study tools was 0.89, which presented that the questionnaire is appropriate for examining the use of Twitter for scientific engagement among Saudi women and its role in empowering them. Table 2 demonstrates the reliability of the study tools.

Table 2: Reliability of the Study Tool

Items	Corrected Item-Total Correlation	Values of Cronbach's Alpha
Twitter as a tool for scientific engagement		
Twitter is a tool to develop knowledge about science and its related topics	.781	.878
Twitter has a science community of learners	.907	.875
Twitter is important to improve your research skills in the field of science	.885	.875
Twitter is important to	.857	.877

Items	Corrected Item-Total Correlation	Values of Cronbach's Alpha
increase your educational knowledge		
Tweet chats (focusing on support for assignment) shared relevant knowledge and perception of peer support due to an increased level of engagement with other students	.869	.876
Twitter Empowers Women in Saudi Arabia		
You feel Twitter voices your rights	.877	.876
Twitter account has changed your way of thinking	.865	.876
I can express myself clearly and freely through Twitter	.887	.876
Do you feel Twitter enhanced your decision–making capacity	.910	.875
Twitter increases your self-confidence and self-esteem	.408	.902
Feeling much less isolated from others (particularly other supportive women) and, as a result, experiencing greater well-being, happiness, and enjoyment of life	.864	.876
Twitter helps you find jobs and other opportunities	.827	.877
Total		.892

3.7. Data Analysis

The study quantitatively analyzed the Statistical Package for Social Sciences (SPSS), version 27. Descriptive statistics are an important statistical approach to analyzing the data. The study of Oancea and Punch (2014) advocated that descriptive analysis allows researchers to examine the data closely and provides insights about each construct across the survey participants by summarizing the information collected. Furthermore, one-way analysis of variance

(ANOVA) and linear regression analysis has also been employed as the statistical analysis in this study.

The qualitative data has been analyzed based on two themes: Twitter as a tool for scientific engagement, the advantages and disadvantages of Twitter as a learning tool, and empowerment through Twitter.

4. Results & Discussion

This section demonstrated the results of quantitative and qualitative analysis to investigate a deeper understanding of Twitter's role as a tool for scientific engagement among Saudi women and evaluate its role in empowering Saudi women in science and education.

4.1. Quantitative Analysis

For quantitative analysis of the study, tables 3 and 4 demonstrated descriptive statistics and frequency distribution for items of Twitter as a tool for scientific engagement respectively. We found that Saudi women moderately perceived Twitter as a tool for scientific engagement with an overall mean score of 3.82 and a standard deviation of 0.82. This indicated the moderate level of acceptance among Saudi women that Twitter has significantly played a role in their educational learning. Moreover, the items "Twitter has a science community of learners" and "Twitter is important to increase your educational knowledge" had the highest mean scores (3.82 and 3.83) with standard deviations of 0.8 and 0.81 respectively. In other words, these results indicated that Twitter is an important tool to enhance scientific engagement among female students in Saudi Arabia. Furthermore, our results are in line with the study of Lopez-Goni and Sanchez-Angulo 2018 which stated that Twitter broadens the interaction, dynamics, and accessibility to millions of people, acting as an informative tool for communication in science and for social learning. In addition, the study by Taylor and Weigal (2016), mentioned that Twitter provides a platform for students to communicate with scientists who can address several key concepts in their discipline.

The results of Table 4 showed that 70 % of female students in Saudi Arabia agreed that Twitter helps to develop knowledge about sciences and its related subjects while only 13% of females disagreed. Moreover, 72% of females perceived that Twitter improves their research skills and as well as improves their

knowledge related to their discipline. It is also observed that 73% of female students believed that Twitter has a science community for learners and only 3% disagree with this statement. Thereby, 71% of students agreed that tweet chats increased their level of participation in assignment-related discussions and their engagement with other students.

Table 3: Descriptive Analysis for Items of Twitter as a Tool for Scientific Engagement.

Items	Means	Standard deviation
Twitter is a tool to develop knowledge about science and its related topics	3.82	.860
Twitter has a science community of learners	3.84	.800
Twitter is important to improve your research skills in the field of science	3.82	.824
Twitter is important to increase your educational knowledge	3.83	.813
Tweet chats (focusing on support for assignment) shared relevant knowledge and perception of peer support due to an increased level of engagement with other students	3.82	.832
Total	3.82	0.82

Table 4: Frequency Distribution of the responses for Twitter as a tool for Scientific Engagement

Items	Scale	Frequency	Percentage
Twitter is a tool to develop knowledge about science and its related topics	Strongly Disagree	19	4.8
	Disagree	13	3.3
	Undecided	37	9.3
	Agree	283	70.8
	Strongly Agree	48	12.0
Twitter has a science community for learners	Strongly Disagree	15	3.8
	Disagree	13	3.3
	Undecided	35	8.8
	Agree	294	73.5
	Strongly Agree	43	10.8

Items	Scale	Frequency	Percentage
Twitter is important to improve your research skills in the field of science	Strongly Disagree	14	3.5
	Disagree	20	5.0
	Undecided	34	8.5
	Agree	288	72.0
	Strongly Agree	44	11.0
Twitter is important to increase your educational knowledge	Strongly Disagree	14	3.5
	Disagree	17	4.3
	Undecided	36	9.0
	Agree	288	72.0
	Strongly Agree	45	11.3
Tweet chats (focusing on support for assignment) shared relevant knowledge and perception of peer support due to an increased level of engagement with other students	Strongly Disagree	16	4.0
	Disagree	16	4.0
	Undecided	38	9.5
	Agree	286	71.5
	Strongly Agree	44	11.0

Tables 5 and 6 demonstrated descriptive analysis and frequency distribution for the items of women empowerment respectively. Table 5 indicated that the overall mean score for items of women empowerment was 3.84 with a standard deviation of 0.93. This highlighted the significance of Twitter in empowering women. The items "Twitter increases your self-confidence and self-esteem", "I can express myself clearly and freely through Twitter" and "You feel Twitter enhanced your decision–making capacity" had the highest mean scores of 3.94 and 3.83 respectively. This indicated that Twitter promotes freedom of speech, enhances their self-confidence, and also improves their decision-making capacity. The study by Gangwani et al. 2021 also found that the use of social media helps female users to gain information and knowledge in several fields. In addition, social media makes communication easier and they can express themselves easily without any hesitation. Moroojo et al. (2023) also highlighted the potential of social media

in women's empowerment promoting creativity in women and broadening their vision and perceptions to play their productive part in the economy.

Table 6 revealed that most of the female students agreed that Twitter has a significant role in women's empowerment by making voices for their rights (70.5), clearly expressing their opinions through Twitter (73%), enhancing their decision-making capacity (73.3%), improves their self-esteem and self-confidence (72.8%), increase their participation in discussions so they feel less isolated (71.8) and also provide help in finding employment opportunities (70.5).

Table 5: Descriptive Analysis for Items of Women Empowerment

Items	Means	Standard deviation
You feel Twitter voices your rights	3.80	.833
Twitter account has changed your way of thinking	3.82	.835
I can express myself clearly and freely through Twitter	3.84	.805
Do you feel Twitter enhanced your decision–making capacity	3.84	.806
Twitter increases your self-confidence and self-esteem	3.94	1.647
Feel much less isolated from others (particularly other supportive women) and, as a result, experience greater well-being, happiness, and enjoyment of life.	3.83	.816
Twitter helps you find jobs and other opportunities	3.81	.830
Total	3.84	0.93

Table 6: Frequency Distribution of the Responses for the Significance of Twitter in Women's Empowerment

Items	Scale	Frequency	Percentage
You feel Twitter voices your rights	Strongly Disagree	15	3.8
	Disagree	18	4.5
	Undecided	41	10.3
	Agree	282	70.5

	Strongly Agree	44	11.0
Twitter account has changed your way of thinking	Strongly Disagree	16	4.0
	Disagree	17	4.3
	Undecided	36	9.0
	Agree	287	71.8
	Strongly Agree	44	11.0
I can express myself clearly and freely through Twitter	Strongly Disagree	13	3.3
	Disagree	19	4.8
	Undecided	32	8.0
	Agree	292	73.0
	Strongly Agree	44	11.0
Do you feel Twitter enhanced your decision–making capacity	Strongly Disagree	15	3.8
	Disagree	14	3.5
	Undecided	34	8.5
	Agree	293	73.3
	Strongly Agree	44	11.0
Twitter increases your self-confidence and self-esteem	Strongly Disagree	12	3.0
	Disagree	13	3.3
	Undecided	37	9.3
	Agree	291	72.8
	Strongly Agree	46	11.5
Feel much less isolated from others (particularly other supportive women) and, as a result, experience greater well-being, happiness, and enjoyment of life.	Strongly Disagree	15	3.8
	Disagree	15	3.8
	Undecided	39	9.8
	Agree	287	71.8
	Strongly Agree	44	11.0
Twitter helps you find jobs and other opportunities	Strongly Disagree	15	3.8

Disagree	17	4.3
Undecided	41	10.3
Agree	282	70.5
Strongly Agree	45	11.3

The presented table 7 presents an analysis investigating Twitter's influence on the scientific engagement of Arab women. The statistical analysis shows that Twitter emerges as a valuable tool for nurturing knowledge about science and related subjects among Arab women, with a statistically significant impact (p-value=0.020). Secondly, the platform seems to harbor a vibrant science community for learners, significantly contributing to the engagement of Arab women in scientific topics (p-value=0.001). Moreover, Twitter appears to hold substantial importance in enhancing research skills (p-value=0.003) and augmenting educational knowledge (p-value=0.004) among this demographic. Tweet chats specifically support assignments and peer engagement which contributes to improved knowledge perception and peer support among Arab women who are interested in science according to a p-value of 0.006. The study reveals how Twitter serves as an essential platform for Arab women scientists who utilize it to share knowledge and develop educational relationships and mutual assistance networks throughout scientific discussions.

Table 7: ANOVA Test for the Role of Twitter on Scientific Engagement.

Items	Sum of Squares	Mean Square	F	Sig.
Twitter is a tool to develop knowledge about science and its related topics	5.772	2.886	3.961	.020
Twitter has a science community for learners	8.805	4.402	7.097	.001
Twitter is important to improve your research skills in the field of science	7.994	3.997	6.032	.003
Twitter is important to increase your educational knowledge	7.197	3.599	5.568	.004
Tweet chats (focusing on support for assignment) shared relevant knowledge and perception of peer support due to an increased level of engagement with other students	6.940	3.470	5.114	.006

The influence of Twitter on women's empowerment in Saudi Arabia is analyzed through the following Table 8. The results revealed that Twitter is a potential instrument for empowering women in Saudi Arabia. It is noticeable that there is a statistically significant difference in the average score of female responses between the seven items mentioned in the below table. This indicated that each item has a significant impact on women's empowerment and has a significant association. Moreover, twitter seems to enhance the decision-making capacity of women (p-value=0.001), helping them to raise their voices for their rights (0.01) which significantly contributes to empowering Arab women. In addition, Twitter has significantly changed the way of thinking in Arab women with a p-value of 0.02. Additionally, Twitter offered a platform to Arab women to express their opinions clearly (p-value = 0.01) and also provided opportunities to find jobs related to their discipline (0.01). however, Twitter has an insignificant impact on their self –confidence but they feel less isolated when they interact with others on Twitter (p-value= (0.01). in other words, Twitter is a potential platform that supports the idea of women's empowerment where women can interact and communicate to enhance their knowledge and capabilities. The study of Zafar et al. 2019 supported our results that social media empowers women by offering them significant benefits such as rapid sharing of information, flexibility, and a wide range of opportunities through large access to the market. Moreover, Alammary 2022 has found Twitter has a significant impact on women's empowerment in Bahrain.

Table 8: ANOVA Test for the Role of Twitter on Women's Empowerment

Items	Sum of Squares	Mean Square	F	Sig.
You feel Twitter voices your rights	6.103	3.052	4.476	.012
Twitter account has changed your way of thinking	5.115	2.557	3.716	.025
I can express myself clearly and freely through Twitter	8.703	4.351	6.917	.001
Do you feel Twitter enhanced your decision–making capacity	8.805	4.402	6.983	.001
Twitter increases your self-	2.611	1.306	.480	.619

Items	Sum of Squares	Mean Square	F	Sig.
confidence and self-esteem				
Feeling much less isolated from others (particularly other supportive women) and, as a result, experiencing greater well-being, happiness, and enjoyment of life	8.813	4.406	6.808	.001
Twitter helps you find jobs and other opportunities	4.084	2.042	2.993	.051

Table 9 presents the regression analysis to investigate the impact of Twitter on the scientific engagement of Arab women and also examine its influence on women's empowerment. the results of linear regression indicated that the use of Twitter by Saudi women has a highly significant impact on their engagement in the field of science and its related subjects (p-value=0.00). The value of R was 0.83 which indicates a high degree of correlation between the variable. Similarly, Twitter also significantly influences women's empowerment with p-value=0.02 and its R-value also shows a high degree of correlation with 75%.

Table 9: Regression Analysis

Variables	R	R Square	Adjusted R Square	Std. Error of the Estimate	F-statistics	p-value
Scientific Engagement	.832	.701	.748	896.503	65.387	.000
Women Empowerment	.753	.623	.651	.503	45.342	.029

4.2. Qualitative Analysis

The qualitative analysis has been constructed on two themes. The characteristics of the female respondents, such as age, their field, and their level of education, are demonstrated in Table 10.

Table 10: Demographics of Study Participants

Participants	Age	Level of Education	Field
P1	30	Graduate	Engineering
P2	25	Graduate	Medical
P3	33	Undergraduate	Engineering
P4	35	Graduate	Science & technology

Participants	Age	Level of Education	Field
P5	30	Graduate	Chemistry
P6	28	Undergraduate	Mathematics
P7	36	Undergraduates	Medical
P8	34	Graduate	Biotechnology
P9	30	Graduate	Mathematics
P10	32	Graduate	Computer science
P11	33	Graduate	Computer science
P12	32	Graduate	Biotechnology
P13	31	Undergraduate	Physics
P14	34	Graduate	Science & technology
P15	34	Undergraduate	Science & technology
P16	30	Graduate	Nursing
P17	35	Graduate	Computer science
P18	29	Undergraduate	Biotechnology
P19	31	Undergraduate	Engineering
P20	35	Graduate	Mathematics

4.3. Twitter as a tool for scientific Engagement

Student–administered learning refers to students learning without asking for teacher guidance based on their needs. We found that students used Twitter for educational purposes to support their studies. Further, respondents highlighted two important motives for using Twitter: exploring their academic field more and increasing their research skills. In addition, respondents were also involved in using different features of Twitter, including direct messages, likes, Tweets, Followers, and Retweets. Moreover, participant 4 responded that by using Twitter, they learn more and get more knowledge related to their field.

"I am a student of the discipline of science and technology; thus, I am more into following the accounts related to technological innovations in science, such as artificial intelligence. These accounts benefit me by allowing me to gain knowledge about the concepts related to my field that I did not learn through classroom interaction.

Therefore, I am responsible for learning by myself, not only depending on my university teachers". Moreover, participant 11, who was a graduate student, stated that;

"Twitter helped me a lot to get a deeper knowledge of the topics related to my academic field as I took a course for remote learning. I feel that Twitter expands my range of information and scope".

The above statements showed that respondents utilize Twitter to complement their studies. They educate themselves by following education-related accounts. Essentially, they sounded as if they observed that the education provided by the university was not enough, and ultimately, they used Twitter to widen their intellectual prospect. Supplementary knowledge presented in the workplace could help students at the university level thereby improving their educational results and expanding their professional domain knowledge. Supplementary information related to engineering practices offered support to students who attended university thereby helping them achieve better learning results and expand their knowledge base. Students in parallel educational environments commonly use social media platforms to enhance their academic development according to previously gathered research. Research participants agree that Twitter provides better access to specialized knowledge along with self-learning opportunities but they differ on how much organized curriculum Twitter should be part of the current study benefits from these insights by demonstrating how Saudi female students uniquely navigate and utilize Twitter for educational purposes.

The research investigated social learning in science and education as an empowerment strategy although empowerment manifests itself in multiple different ways beyond the boundaries of scholarly and scientific domains. The essential elements of empowerment also consist of economic self-sufficiency alongside political involvement and the capacity to govern oneself socially. Through Twitter, women have found employment opportunities and launched gender rights discourses that support social movements that strive for improvement. The examination of different dimensions regarding women's empowerment through digital platforms needs further investigation to build complete knowledge (Iliya et al., 2022). In addition, some of the respondents used the like feature of Twitter to save the tweet's information. Participant 14 stated, "I use the feature of like on Twitter to retain the knowledge I wished to read

lately". However, participant 19 used Twitter's like feature in a more complicated manner, she added;

The "Like" feature of Twitter is very helpful for me. I like tweets that contain useful information related to my discipline (Engineering) and wish to read later. If you glance at my list of likes, you will see books, publications, websites, and references that enable me to cite their sources in my research-related work. "

Some participants mentioned that they also do DMs to the teachers of their university, even to teachers from other universities, when they have any query related to their subjects, and they also follow their teachers on Twitter to get updated about the academic field. Participant 5 said that;

"I found Twitter very helpful in my master's as I used Twitter to take advice from many university teachers regarding my research. I also followed research-related accounts that have been useful in writing my research proposal".

Participant 8 mentioned that she used to DMs for long conversations related to her academics; she further stated, "I contacted the professor in Turkey to ask her advice on my research subject and whether it is worth researching. I prefer DMs to have private discussions related to my subjects. In that way, my work cannot be plagiarized". Participants mentioned that they used Twitter to ask their teachers queries related to their academic courses.

Participants' responses indicated that Twitter is commonly used by students to get more information about their academic discipline, improve their research skills, and prepare for further studies.

Participants mentioned that they used Twitter to ask their teachers queries related to their academic courses. Participant 8 said,

"My professor tweeted related to distinct forms of research methodologies, asked him by his tweet to kindly elaborate on it, and he did it".

Participant 20 stated that few of her teachers reserve specific hours to reply to their students' queries related to their courses; she further said, "Our professor instructed us that she had set two hours to respond to our queries after the lecture. So I asked her about the complicated concept that had been taught in the lecture, and she responded to me."

Some participants advocated that few of their teachers did not reply to DMs and preferred public interaction. Participant 15 stated,

"Most of my professors said that we were asked to ask questions related to our academic discipline by tweeting publicly instead of using the DM feature so that the teacher's reply to our questions helped other students".

Participant 4 added, "My science teacher mentioned on his Twitter profile that he would only respond to public tweets and not reply to any queries asked through DMs."

However, some teachers were hesitant to interact publicly and did not want to communicate with their students on a public platform. Participant 17 added, "Many of my professors did not want to discuss anything about the courses at the university as they believed that it was a very delicate and cognizant topic that should not be debated related to it".

To explore the female student's perception of the field of science and the potential of Twitter as a tool for scientific engagement, it is important to understand how these female users perceived their academic identities and self-presentation on Twitter. Participant 2 claimed, "Offline presentation is more manageable than online settings. In physical settings, many factors define individuals, such as their body language and clothes; however, online settings restrict the capabilities of people to lead their self-identities and restrain their influence on the audience compared to the physical environment".

Participant 18 also highlighted that "Self-presentation through online settings can become problematic as it is sometimes operated for diversified and unknown audiences. However, the users of Twitter can indirectly communicate with the anonymous audience and can share his/her academic knowledge with them".

Anonymity on social media motivated female users to share their academic thoughts that they felt reluctant to present in conventional classroom settings. Participant 20 stated, "I found Twitter is a potential tool as it offers a substitute for the shy student to improve their interaction and encourage them to share and present their thoughts with others that ultimately represent their academic individualities to others".

Furthermore, participant 2 also mentioned the positive impact on self-presentation through the use of Twitter and stated that "I found interaction with science specialists on Twitter offered an opportunity to enhance my academic profile, improved my range of horizons to the wider academic science community, and had a positive influence on my academic performance."

It is also observed that women use Twitter to educate themselves by following their discipline-related accounts. In other words, Twitter complements their studies. Furthermore, the participants' responses also highlight the importance of Twitter in increasing their research skills, enhancing their learning outcomes, and broadening their knowledge related to their field. They also used different features of Twitter to increase their range of horizons and enhance their communication and interaction with their teachers, peers, and even experts in their field worldwide.

4.4. Twitter's Role in Women's Empowerment

As discussed above, in Saudi Arabia, women used Twitter as an instrument to commence an interaction in their culture to replace the gender codes that control actions and ask for gender equality. Twitter has enhanced participation in dialogue and helped extensively in attaining the target of gender equality. Consequently, online spaces provide a medium for women to express their views and opinions through blogging, which leads to psychological empowerment. Most participants advocated that they experience freedom of speech through Twitter as they can express their opinions related to their courses; Participant 17 stated that.

"Twitter provides you a platform to express your perceptions and opinions through hashtags while being present at your home, and these hashtags have started to trend and are read by thousands of individuals. It is a very influential and significant instrument to present their ideas and opinions". Further added by Participant 18 about the freedom of speech offered by Twitter,

"I spend hours daily on Twitter as it is part of my routine and an appropriate learning tool. I adore the freedom of speech and power of writing provided by Twitter, as I write whatever wanted to write since the information is related to my course".

Participant 20 also expressed their views about the self-confidence she got through using Twitter. It said, "I am a very shy person and unable to speak publically, but due to social media, I am confident enough to express my views and opinions openly through the platform of Twitter without any fear of speaking in front of the public".

Moreover, Participant 7 enlightened me on the significance of Twitter and its impact on the offline world. She added, "I had an idea related to one of the modules, so I tweeted that idea. Many of my

classmates who had accounts on Twitter liked my idea and motivated me to present it to our teacher at university. After discussing it with the teacher, my idea became a reality. Thanks to God".''

Participant 15 encountered some unpleasant tweets, and she shared how Twitter made her voice change the perception about Saudi women somehow and added, "I provided my opinions on hashtags about Saudi women having narrow or particular thinking. It hurts me to know what people of the world perceive about Saudi women. I need to rectify some of these incorrect opinions by generating hashtags, and I feel these hashtags improved a few of these opinions".

Females acknowledged that Twitter has impacted the way of communicating with the opposite gender in Saudi Arabia. However, only a few participants agreed that Twitter did not segregate them from men. Participant 16 mentioned, "I do not feel any segregation in gender on Twitter. I can equally express my concerns and issues related to my research on social media".

However, participant 12 provided a different perspective. It said, "There is segregation prevailed on Twitter as I felt much discrimination. Women are easy targets in the form of humiliation and violent content posted on Twitter".

The above statements revealed that Twitter is an influential and powerful platform for women where they can express their views and opinions. The participants' responses also illuminated the role of Twitter in providing them freedom of speech, self–confidence, and self-esteem in terms of expressing their views in public without any hesitation or fear of speaking in public. Although some women experience discrimination on Twitter, most women don't feel any segregation in gender on Twitter.

5. Study Limitations and Future Directions

The results of this study are limited as it only focuses on Twitter as a social networking site. Future studies can evaluate how students use other social networking sites, including Instagram, Facebook, and other social media platforms, for their academic purposes, and they can also interact with Twitter and other social media platforms. Another limitation of this study is that it only focused on the opinions of female students towards empowerment; however, male perception also matters for comprehensive understanding. Future studies must focus on both males and females to investigate the role of media towards empowerment for a deeper knowledge of the idea.

6. Conclusion

This study investigates the perceptions of women towards using Twitter as a learning tool in science and its related fields among Arab women, particularly in Saudi Arabia. Moreover, this study also highlighted the role of Twitter in shaping women's empowerment. In this study, we employed a mixed methods approach, including qualitative and quantitative analysis, to gain a deeper understanding. Our study found that women in Saudi Arabia moderately perceived Twitter as a significant tool for learning, as Twitter provides them with a platform to enhance their knowledge and information related to their academic discipline. Twitter offered them a science community where learners could interact and communicate with science specialists who could address their queries. Further, Twitter comprehensively enhanced their research skills in the field of science as women can freely follow the accounts on Twitter where they find help in writing their research proposals, theses, and dissertations. Saudi women adore the freedom of speech offered by Twitter, where they can express their thoughts and ideas related to their academic courses. Twitter also helped shy female students who feared public speaking and were uncomfortable sharing their opinions, providing them a platform to speak without fear of the public.

We found that most female students used Twitter to support their academic studies and complement them by giving them a deeper knowledge of the topic. Twitter also helped students resolve their academic queries. Moreover, this study revealed that Twitter has emerged as the potential platform for students where they can communicate and interact to enhance their knowledge in their specific fields. Twitter significantly plays a role in science by increasing their research skills and knowledge related to science subjects. Also, through tweet chats, students can engage with their peers to get help with their assignments. In a nutshell, this study provides insights into how Twitter empowers women in Saudi Arabia by helping them in their academics as a learning tool, self-confidence, and self-esteem in expressing their opinions fearlessly, and they feel less isolated as they enjoy collaborative learning through Twitter.

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