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Trend of STEM education in Indonesia: social network analysis of Platform X

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Abstract

Purpose – This study aims to explore the themes of science, technology, engineering and mathematics (STEM) education conversations in Indonesia on Platform X.

Design/methodology/approach – This study employs a social network analysis approach to examine the trends of STEM education in Indonesia based on discussions on Platform X (formerly Twitter). The data were collected using Platform X search queries with relevant keywords, including "STEM," "education," "pendidikan" and "Indonesia." The study extracted a total of 17,650 X users whose recent tweets contained these keywords, as well as those who were replied to or mentioned in the tweets. The data collection period spanned from January 1, 2024, to December 5, 2024. The extracted data were analyzed using NodeXL to generate a network graph and identify key clusters, influential users and engagement patterns.

Findings – The analysis of top influencers on X reveals a diverse ecosystem of individuals, institutions and media entities dynamically advocating STEM education in Indonesia. Their collective efforts give a positive indication about the nationwide commitment to prioritizing STEM education. The findings reported that some hashtags highlighted the importance of guruhebat, which is understood as excellent teachers. This shows that excellent teachers are the hope of most Indonesian people who are voiced through social media.

Originality/value – The findings could be of value for the leader, educators and policymakers to support and provide a good learning environment for STEM teachers in Indonesia to increase the education quality as well as the public trust.

Keywords Education, Platform X, SNA, STEM, Social media

Paper type Literature review

Introduction

Recently, the promotion of science, technology, engineering and mathematics (STEM) education has come under scrutiny due to the shortage of STEM workforce. The application of STEM education not only equips students with conceptual knowledge but also technical skills and problem-solving abilities needed to answer challenges in various industrial fields (Hebebci & Usta, 2022; Tan, Ong, Ng, & Tan, 2023). Research shows that the application of STEM in learning can encourage students to think critically (Agussuryani, Sudarmin, Sumarni, Cahyono, & Ellianawati, 2022; Hacıoğlu & Gülhan, 2021; Rahmawati, Rizal, & Lathifah, 2021), think creatively (Marsono, Khasanah, & Yoto, 2019; Putri, Pursitasari, & Rubini, 2020) and collaboratively (Hadiyanti *et al.*, 2021; Nurtanto, Pardjono, Widarto, & Ramdani, 2020), which are essential skills in facing the challenges of the increasingly complex and dynamic 21st-century world of work (Akgunduz & Mesutoglu, 2021). In addition, STEM education can have an impact on increasing students' interest in STEM fields and encouraging

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students to consider careers in these fields (Akgunduz, 2016; Baran, Bilici, Mesutoglu, & Ocak, 2019; Martín-Páez, Aguilera, Jiménez-Liso, & Perales-Palacios, 2019).

Specifically, STEM education in Indonesia has developed rapidly, although until now there has been no official government policy governing its implementation in the national curriculum (Ardwiyanti, Prasetyo, & Wilujeng, 2021). Various empirical studies have begun implementing STEM education in all level, from elementary to higher education. The application of STEM in elementary education focuses on cognitive development and creativity through explorative activities (Putri, 2019; Amalia, Sutarto, Kurniawati, & Pranoto, 2021) to improve 21st-century skills as well as for the development of learning models and media (Perdana, Apriani, Richardo, Rochaendi, & Kusuma, 2021; Widarti, Rokhim, & Syafruddin, 2020). Meanwhile, in vocational high schools, STEM is more focused on preparing job skills through the engineering design process (Nurtanto *et al*., 2020) to higher education, which has integrated STEM in various study programs such as science education, biology and biophysics (Rusydiyah, Indrawati, Jazil, Susilawati, & Gusniwati, 2021; Kurniati, Suwono, & Ibrohim, 2020; Hidayati & Irmawati, 2019).

However, the level of implementation in schools is still relatively limited. Empirical data show that only a small proportion of teachers have consistently implemented STEM learning, due to limited interdisciplinary understanding, high demands for cross-disciplinary mastery of material and a lack of practical guidelines for STEM learning (Permanasari, Rubini, & Nugroho, 2021). The implementation of STEM education in Indonesia still faces challenges, especially regarding the readiness and understanding of teachers as the main implementers of learning. Although STEM has been recognized in education reform, increased awareness, policy support and the provision of guidelines and ongoing training are needed for its optimal implementation. In addition, differences in schools' perceptions of the form and strategy of STEM integration indicate the need to develop standardized but adaptable learning models and teaching materials for the local context. This effort is important to ensure that STEM education can be effectively implemented to support the development of 21st-century skills in Indonesia (Nugroho, Permanasari, & Firman, 2019).

In line with the times, especially the era of the Industrial Revolution 4.0, STEM education in Indonesia is expected to develop 21st-century skills that are needed by students to adapt to an increasingly science and technology-based world such as the use of social media (Nugroho, Permanasari, Firman, & Riandi, 2021). Social media plays an important role in supporting and promoting STEM education, especially in the context of increasing student interest and strengthening the educational community. Adnan *et al*. (2021) emphasized that social media offers an effective solution to the challenge of low student interest in STEM study programs. In the context of education, social media is used to build communication, collaboration, and marketing strategies that are able to reach a wide audience through platforms such as Facebook, Twitter and Instagram. In addition, by utilizing big data analytics, educational institutions can access deep insights into audience behavior and preferences that are useful in developing more relevant and personalized promotional strategies (Ghani, Hamid, Hashem, & Ahmed, 2019; Shaikh, Shinde, & Borde, 2017). However, there are challenges in determining the right content strategy and audience segmentation. Therefore, the development of social media-based frameworks must go through a trial-and-error process involving technologies such as artificial intelligence and big data analytics for success (Adnan, Hassan, & Zulkefli, 2020; Stieglitz, Mirbabaie, Ross, & Neuberger, 2018).

Pickering, Yuen, and Wang (2016) research shows how social media, particularly Twitter, is used as a strategic communication channel in STEM education. Twitter is one of the social media platforms that can be used in STEM education. The use of Twitter allows for the rapid and widespread dissemination of information about STEM. It also helps connect various stakeholders including educators, students, policymakers and industry to share information and discuss issues in the STEM world (Suh, Hong, Pirolli, & Chi, 2010). The analysis of STEM social networks on Twitter shows that opinion leaders in the STEM community are mostly from organizations, such as government agencies, companies and STEM education non-profit organizations. These organizations are the main sources of information and opinions relevant to the STEM education community. Nonetheless, individuals also play an

active role in the conversation, with many users engaging in discussions about STEM. Therefore, the use of social media such as Twitter allows the STEM industry to reach a wider audience, disseminate STEM-related information and facilitate conversations involving various stakeholders. Thus, social media not only serves as a platform for sharing information but also as a tool for networking and strengthening the STEM education community, as well as for preparing a competent future workforce in STEM fields (Pickering *et al.*, 2016). Furthermore, Knaub, Henderson, and Fisher (2018) explained that analytical approaches such as social network analysis (SNA) can also be used to understand the relationships within the STEM education community, both educators and students. Educators with high connectedness in discussion networks tend to act as change agents in teaching innovation (Daly, 2010; Coburn, Russel, Kaufman, & Stein, 2012). Thus, social media and social network analysis approaches can be used synergistically to support the development of more effective and sustainable STEM education.

Given the importance of social media in popularizing STEM for the community, it needs a deep analysis of the conversation about STEM in the social media. Platform X, as the one of most popular social media, is being used by all generation to share of any idea, opinion and feeling of community about trending issues, which become potential media to STEM conversation. So forth, this research will answer the research question: "What are the themes of the STEM education conversation in Indonesia on Platform X?"

Methods

Research design

This study employs a SNA approach to examine the trends of STEM education in Indonesia based on discussions on Platform X (formerly Twitter). The study systematically analyzes interactions, influence and content shared by users engaging with STEM education-related topics.

Data collection

The data were collected using Platform X search queries with relevant keywords, including "STEM," "education," "pendidikan" and "Indonesia." The study extracted a total of 17,650 X users whose recent tweets contained these keywords, as well as those who were replied to or mentioned in the tweets. The data collection period spanned from January 1, 2024, to December 5, 2024. To ensure relevance and engagement, inactive accounts (those without posts in the past 6 months) and accounts with fewer than 100 followers were excluded from the analysis.

Data analysis

The extracted data were analyzed using NodeXL to generate a network graph and identify key clusters, influential users and engagement patterns. The analysis included:

(1) Social network structure

The study examined how digital learning accounts interact within Platform X. The network was visualized using a NodeXL-generated graph, identifying community clusters that reveal the connectivity and engagement of users discussing STEM education.

(2) User influence and engagement

Users were ranked based on betweenness centrality and in-degree and out-degree centrality to identify the most influential accounts within the network. The top 10 influential users were analyzed in terms of their account types, follower counts and levels of engagement in STEM education discussions.

(3) Hashtag and content analysis

The most frequently used hashtags were identified to determine recurring themes and topics within STEM education discussions. The top 10 hashtags were examined to understand the dominant discourse, with special attention given to those directly related to Indonesia's education system.

(4) Shared content and resources

The study analyzed the most frequently shared Uniform Resource Locators (URLs) to identify key resources and platforms that contribute to the STEM education discourse in Indonesia. These URLs provided insight into the types of information sources that users rely on and share within the network.

Ethical considerations

The study adhered to ethical guidelines by only collecting publicly available data and ensuring user anonymity in data reporting. No personally identifiable information was disclosed, and all analyses focused on aggregated data trends rather than individual user behavior.

This methodological approach allows for a comprehensive understanding of the discourse surrounding STEM education in Indonesia on Platform X, highlighting key trends, influential actors and thematic focuses in the digital learning ecosystem.

Result

Social network analysis for Indonesia education content

As shown in Figure 1, the network graph visualizes interactions and discussions surrounding digital learning accounts on X (formerly Twitter), which are operated by both organizations and individuals to share information. The clusters signify various groups engaged in

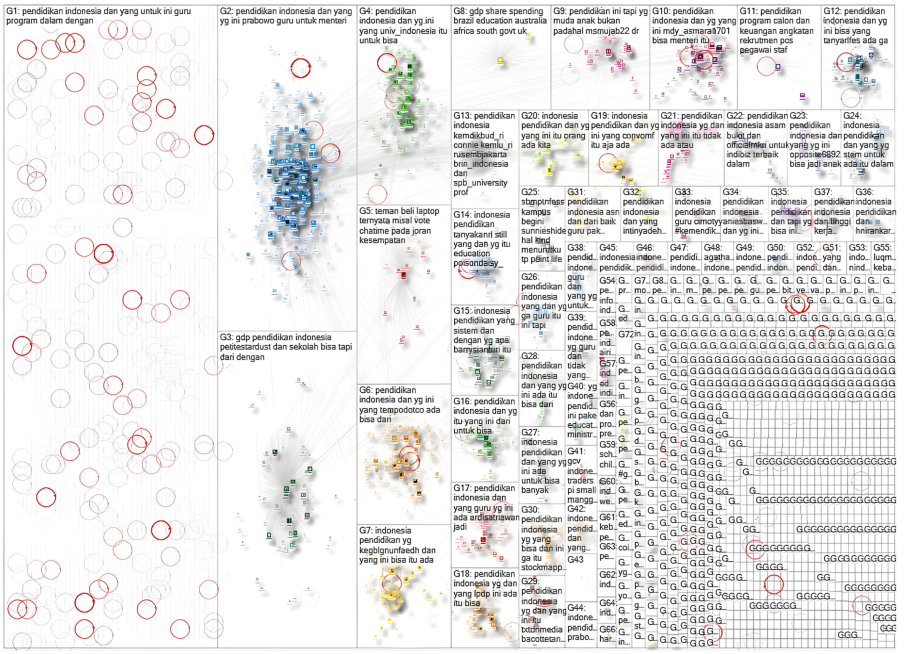

Figure 1. NodeXL graph for STEM education-related account on X

interconnected discussions, each focusing on Indonesia education topics in Indonesia. The size of the nodes and the density of their connections indicate the influence and activity level of these accounts in facilitating conversations.

The analysis identifies the graph cluster as community clusters (see Figure 1). Community clusters feature a collection of medium sized groups, rather than a crowd of mostly unconnected Twitter users. It implies that there are large numbers of disconnected contributors who mention the topics related to Indonesia education but do not link to one another. Additionally, community clusters have bigger and more interconnected groups. The results also indicate that the subject matter of digital learning is discussed widely on X among many disconnected participants. Hence, brand clusters focus on brand-mentioning participants in which they discuss digital learning but likely not connect to each other.

The NodeXL-generated network graph identifies a total of 1,138 distinct groups, with 10 major groups being the most prominent. Group 1 emerges as the largest group. Visual representations of social media connections display various network structures, which help explain group dynamics revolving STEM and Indonesia education. These structures reveal how individuals and organizations connect across Indonesia and spread the related information within the network.

Overall graph metrics

The overall graph metrics were presented in Table 1. The analysis indicated that there were 17,650 X users in the entire network. As shown in Table 1, the study reported the top 10 key players among all X users based on the magnitude of the in-degree centrality. The findings revealed several key perspectives on STEM education and Indonesia education as the topic of conversation focused on different areas with the Indonesia education as the central theme.

User analysis

Table 2 presents a ranking of influential users based on their betweenness centrality and provides a description of their accounts. Users are ranked according to their betweenness centrality scores, while the account description outlines the type of account. The betweenness centrality column displays the raw score for each user, whereas the follower column indicates the number of followers associated with each account. Additionally, the group cluster column categorizes users into specific groups, as shown in Figure 1. The follower count reflects the number of followers each user had during the specified period.

Table 1. Overall graph metrics

Metrics	Frequency
Vertices	17,650
Unique edge	19,838
Edges with duplicates	6,768
Total edges	26,606
Self-loops	9,173
Reciprocated vertex pair ratio	0.004090854
Reciprocated edge ratio	0.008148373
Connected components	5,300
Single-vertex connected components	4,241
Maximum vertices in a connected component	9,968
Maximum edges in a connected component	16,573
Maximum geodesic distance (diameter)	22
Average geodesic distance	5.796198
Graph density	5.27921E−05
Modularity	0.640093

Table 2. Top 10 influential users with highest betweenness centrality score

Rank	Description	Followers	Betweenness centrality	In-degree centrality	Out-degree centrality	Group cluster	Tweet
1	Personal account; immigrant; researcher	6,870	36027705.936	1,379	5	3	42,507
2	Akun Resmi Presiden Republik Indonesia ke-8	4,984,937	23321819.757	375	1	2	9,510
3	Journalist	973	10721650.782	533	1	5	33,415
4	Media and news company	2,331,157	8841272.871	179	3	6	1,413,819
5	Official account of Universitas Indonesia	1,253,251	8236828.922	167	1	4	36,696
6	Media and news company	2,907,002	6303098.029	327	1	8	29,738
7	Blogger	12,557,361	5643188.106	198	1	7	23,312
8	Menteri Pendidikan Dasar dan Menengah RI I Sekretaris Umum	49,563	5495982.785	152	1	2	2,561
9	Official account of Otoritas Jasa Keuangan	173,062	5340420.320	275	1	11	22,942
10	Personal account; social talker	90,079	5112691.535	114	4	2	62,754

The findings revealed that the X account that owns the highest follower count (12.5 million) is an Indonesian blogger. Next, the account that owns the most tweets (1.4 million) is a media and news company. This highlights the significant role of the official organization's account on X in reflecting the importance of STEM education in Indonesia. There are four individual accounts that ranked as top-ten influencers about STEM education. The top-ranked influencer is a personal account named "petitestardust". This account is accompanied by a profile hashtag, "#womaninSTEM," indicating her strong role in STEM field and relationship with STEM-related news and posts. Since her inception on X, there are a total of 27 posts related to STEM. Notably, her posts about research and education in STEM garnered hundreds of thousands of views, emphasizing the growing significance of STEM education in shaping academic opportunities and career development. The growing emphasis on the importance of STEM education in Indonesia is further reinforced by the third most influential user, "arvendomh," who frequently advocates for issues related to *Sekolah Menengah Kejuruan* (SMK). In the Indonesian education system, SMK refers to vocational high schools that offer specialized training in fields such as software engineering and other technical disciplines. This account has shared over 30 posts highlighting the value of SMK, underscoring the country's increasing need for STEM-focused education to equip students with practical skills relevant to the modern workforce.

Next, the findings revealed two influential media and news companies contributing to the discourse on STEM education. *Tempo*, ranked as the fourth most prominent account in this category, has published over 60 posts related to STEM. One notable post highlights President Prabowo Subianto's vision for Indonesian education, in which he emphasizes the importance of ensuring that every Indonesian child has access to quality education particularly in the fields of science and technology. Additionally, a few top influencers can be categorized as the official account of the ministerial authorities and higher education institution. "*Akun Resmi Presiden Republik Indonesia ke-8*" is ranked second in the list due to the significant contribution towards the building of healthy school pupils across the nation. The program, "Free Nutritious Meal Program," aims to meet the need for balanced nutrition, support optimal growth and development of children and form a healthy, intelligent and quality generation towards Golden Indonesia era. On November 15, 2024, the president advocated the urgency to be more

accommodating in utilizing technological and digital innovations, with the aims of elevating STEM education and create a better future for the welfare of all people.

Besides, the official X account of Universitas Indonesia has garnered thousands of views for its consistent support in promoting innovative and scientific initiatives within the Indonesian education system. Their posts revolve around research breakthroughs, student-led science projects and collaborations with industry partners, all of which reflect the university's commitment to advancing STEM education. By fostering a culture of innovation and critical thinking, Universitas Indonesia plays a key role in preparing students to meet the demands of the ever-evolving global landscape, where skills in STEM are increasingly essential for success. In short, it indicates the continuous commitment and efforts in supporting STEM education in Indonesia.

To conclude, the analysis of top influencers on X reveals a diverse ecosystem of individuals, institutions and media entities dynamically advocating STEM education in Indonesia. Their collective efforts give a positive indication about the nationwide commitment to prioritizing STEM education. Ultimately, it hopes to equip future generations with the skills needed to thrive in an increasingly technology-driven world.

Top hashtags

The 10 most used hashtags are presented in Table 3. There are 4 hashtags with a frequency greater than 200, ranging from 203 to 285, whereas the remaining 6 hashtags recorded a frequency between 112 and 180. First, the highest number of hashtags is "#Indonesia," recorded a frequency of 285. Following the rank is "#pendidikan," placed at second position with $n = 246$. The latter is understood as education. The third most used hashtag is "#guruhebat."

The fourth most used hashtag is #hgn2024.

The fifth most used hashtag is "#guruhebatindonesiakuat."

The sixth most used hashtag is "#kemendikdasmen."

Last but not least, the seventh most used hashtag ($n = 112$) is "#education."

The hashtag, "#pendidikan," repeatedly appears within Group 1 and Group 2, highlighting the emphasis to enhance education in Indonesia. #Pendidikan, #Indonesia and #education was listed in the top 10 hashtags in entire graph, indicating the dominant appearance of Indonesia education when the topic of STEM education Indonesia is discussed. Additionally, several top hashtags are associated with Indonesia. This implies that the countries are navigating towards STEM education initiatives. The findings reported that both some hashtags highlighted the importance of *guruhebat*, which is understood as excellent teachers. The hashtags #guruhebat, #hgn2024, #guruhebatindonesiakuat and #kemendikdasmen have the same perspective, which are interrelated. Guruhebat is a slogan used for a series of national teacher's day commemorations (#hgn), organized by #kemendikdasmen. This shows that excellent teachers

Table 3. Top hashtags in entire graph

Rank	Top hashtags in tweet in entire graph	Entire graph count
1	Indonesia	285
2	pendidikan	246
3	guruhebat	204
4	hgn2024	203
5	guruhebatindonesiakuat	180
6	kemendikdasmen	144
7	education	112

are the hope of most Indonesian people who are voiced through social media, to become a strong Indonesia (#guruhebatindonesiakuat).

Top URLs

Next, Table 4 illustrates the most shared URLs in tweet within the entire graph. The first URL refers to the main page of *CNN Indonesia*. The second URL is a Google Form titled "How Education Can Shape Indonesia's Environmental Policy," written by Taufiq Ihsan, an academician from Universitas Andalas. The third URL is about the donation page from Happy Hearts Indonesia, a non-profit organization that focuses on rebuilding education for every child in Indonesia, ensuring them with access to education by attending safe and earthquake-resistant schools. The fourth URL is a news article titled "Integrated media technology limited announces memorandum of understanding to develop sourcing channel of halal products in Thailand" by Integrated Media Technology Limited. The fifth URL features an article titled "Telkom Sukses Jalankan Bisnis Tanpa Abaikan Misi Pembangunan 3T" by *CNN Indonesia*. The sixth URL refers to an article titled "Tingkatkan Kompetensi Jurnalis di Indonesia, Dewan Pers Apresiasi BRI Fellowship Journalism 2025," published by Tribunbisnis.

The result shows that mass media is the most account that share related STEM, both in the separate or complete term of integrated STEM. *CNN Indonesia* as the big mass media, mentioned about STEM through their programs, such as "*CNN Indonesia* Tech News program" that specifically broadcasts and discusses the latest news about the development of science, art and technology. The second URL is popular because through this account a Google Form was uploaded to survey how education sharpens environmental policies in Indonesia. This tweet uses a title that attracts many users to repost it, because of the popular environmental issue. Other URLs are also related to mass media (publishers) and focus on news posts related to STEM, especially in how technology and digitalization should be developed to accelerate digital education in schools and improve journalist competence in Indonesia.

Discussion

The result highlights several important things as the point of view to understand the conversation of community about STEM education in Indonesia. The top users are come from personal account, which means, social media has transformed the way individuals

Table 4. Top URLs in entire graph

Rank	URL	Description	Count
1	http://cnnindonesia.com/tv	CNN: Cable news publisher	12
2	https://geotimes.id/opini/how-education-can-shape-indonesias-environmental-policy/	Website	11
3	https://happyheartsindonesia.org/donate-crypto/	Non-profit organization	8
4	https://www.liputan6.com/tekno/read/5758949/platform-pijar-sekolah-jadi-landasan-telkom-untuk-akselerasi-pendidikan-digital-di-indonesia	News publisher	7
5	https://www.cnnindonesia.com/ekonomi/20241016113256-625-1155909/telkom-sukses-jalankan-bisnis-tanpa-abaikan-misi-pembangunan-3t	CNN: Cable news publisher	7
6	https://www.tribunnews.com/bisnis/2024/11/06/tingkatkan-kompetensi-jurnalis-di-indonesia-dewan-pers-apresiasi-bri-fellowship-journalism-2025	News publisher	6

communicate, obtain entertainment and express themselves in the digital space (Yang, Zhang, Cheng, & Zhao, 2023). Influencers attract followers' attention through the production of content that is relevant, interesting and tailored to their followers' interests. Followers often view influencers as role models and place high value on the advice, entertainment and authenticity they display (Misiak, Urbanek, Frackowiak, & Sorokowski, 2025). Influencers build and maintain their audience through the production of relevant, engaging content tailored to their followers' preferences, often perceived as role models due to their authenticity, entertainment value and recommendations that are considered trustworthy by the public. Their presence in the digital space contributes significantly to the formation of public opinion, influences consumption behavior and shapes social trends in society (Han & Balabanis, 2024). Compared to other groups, influencers are considered the most effective in managing persuasion and strategic communication strategies in the digital space. This influence is built through various communication approaches that enable them to form strong relationships with their followers. Therefore, influencers not only act as content creators but also as information intermediaries capable of reaching users on a large scale (Zhang & Lu, 2023).

Furthermore, the top-ranked influencer used profile hashtag, #womaninSTEM. This indicates that the issue of women's interest and role in STEM is of considerable public interest. Women's interest in STEM fields is often hampered by the challenges they face along the way (Dasgupta & Stout, 2014). Research shows that despite women's good academic performance, women still have low self-confidence in STEM fields (Cwik & Singh, 2021; Fisher, Thompson, & Brookes, 2020). This can result in low interest and motivation for women to continue their studies or pursue a career in STEM (Kuchynka, Gates, & Rivera, 2023; Moss-Racusin, Sanzari, Caluori, & Rabasco, 2018). The National Science Foundation (2011) explains that the involvement of women in STEM is very important, not only to support gender diversity and equality but also to strengthen the quality and competitiveness of science and technology. Therefore, greater support is needed, both socially and professionally, as well as the creation of educational and work environments that are inclusive and support the achievement of shared values, to encourage women to survive and thrive in this field (Cwik & Singh, 2021; Diekman, Weisgram, & Belanger, 2015). This implies the importance of campaigning for a better role for women in STEM fields, and social media support is essential.

Meanwhile, the fact that careers in STEM fields are dominated by men may exist in relationships because men's self-efficacy or self-concept beliefs are often shaped by their interpretations of personal accomplishments and successes, whereas women's self-efficacy or self-concept beliefs are more influenced by relational events in their lives (Zeldin, Britner, & Pajares, 2008). This is in line with the results of research by Lu *et al.* (2024), which concluded that female students' STEM aspirations are influenced by parental expectations. Therefore, teachers can work together with parents to create an environment that encourages and supports students in pursuing careers in STEM. It is important for educators to encourage parental involvement and provide resources and guidance for parents to engage effectively in STEM-related activities and discussions with their children.

Another result pointed frequently advocates for issues related to *Sekolah Menengah Kejuruan* or vocational school. Learning in vocational schools has a very distinctive context because it integrates various aspects, such as the basic characteristics of vocational subjects, the real conditions or situations where learning takes place and learning objectives and outcomes that are tailored to the specifications and qualifications of the world of work (Brennan-Kemmis & Green, 2013). In addition, the characteristics of vocational school students who tend to be more applicative and learning styles that prefer hands-on or practical approaches are also a major consideration in designing learning such as project learning (Çevik, 2018; Mulyopratikno & Wiyarsi, 2023; Rahmawati *et al.*, 2021). In this context, the implementation of STEM education becomes very relevant and important. STEM education provides teachers with the opportunity to show students how concepts, principles and techniques from STEM are used in an integrated manner in the development of products, processes and systems that they use in everyday life (Becker & Park, 2011; Moore *et al.*, 2014).

Leaders, teachers and policymakers should work together to encourage the strengthening of STEM learning implementation in vocational schools that are linked to areas of expertise and the world of work to produce adaptable graduates who are able to compete in the future. STEM education will make learning more meaningful for vocational school students, so that they are motivated to become professional workers in the future.

In line with the times, especially the era of the Industrial Revolution 4.0, STEM education in Indonesia is expected to be able to develop 21st-century skills that are greatly needed by students to adapt to a world that is increasingly based on science and technology (Nugroho *et al.*, 2021). *Tempo* as a critical news magazine is usually active in disseminating its content through platforms such as Instagram, Twitter, Facebook and YouTube, including technology trends that are developed in many fields. The role of mass media in developing public perception of STEM education is also shown by *CNN Indonesia* (as the top URL). *CNN Indonesia* is a national television media that has special programs related to discussions about technological developments around the world, with in-depth analysis from various perspectives. The use of mass media and social media plays an important role in supporting and promoting STEM education, especially in the context of increasing student interest and strengthening the educational community. Adnan *et al.* (2021) explained that social media offers an effective solution to the challenge of low student interest in STEM study programs. In the context of education, social media is used to build communication, collaboration and marketing strategies that can reach a wide audience. Research by Pickering *et al.* (2016) explains that the use of media allows for the rapid and widespread dissemination of information about STEM so that it can build networks and strengthen the STEM education community, as well as prepare a competent future workforce in the STEM field.

The development of STEM education shows a shift towards a technology-based learning approach (Ng & Park, 2021; Sungur Gül & Ateş, 2023). Social media has become a strategic digital space for shaping and disseminating STEM discourse through content production, language use and the use of hashtags and online interaction patterns. On platforms such as Twitter, STEM discourse not only serves as a means of disseminating information but also as a social mechanism for increasing the visibility of STEM activities, building community networks and encouraging public participation. The use of affirmative narratives and digital communication strategies contributes to shaping positive perceptions of STEM fields and strengthening the collective identity of the STEM community. Thus, social media plays an important role as a medium for communication, advocacy and informal learning that supports the sustainable development of the STEM ecosystem (Alkhammash, 2019).

Moreover, teachers and education are top hashtags in discussions about STEM on social media in Indonesia. This indicates that the role of teachers in STEM education is crucial to support the development of 21st-century skills that students need to face global challenges and technological developments, especially in the midst of the Industrial Revolution 4.0 (Nugroho *et al.*, 2021). Teacher quality has been shown to be a major factor affecting student achievement, where the quality of teachers' education is closely related to their knowledge and teaching ability, which in turn affects student achievement (Blömeke, Suhl, Kaiser, & Döhrmann, 2012; Kersting, Givvin, Thompson, Santagata, & Stigler, 2012). Therefore, teachers' professional development, both through pre-service and in-service training, is crucial to improve their understanding of materials, pedagogy and the integration of the two, known as pedagogical content knowledge (Shulman, 1987). Research shows that the role of teachers in STEM education is not only limited to teaching the content but also involves shaping students' positive attitudes towards science, technology, engineering and math (Kiazai, Siddiqua, & Waheed, 2020; Morrison *et al.*, 2021; Morris, Slater, Boston, Fitzgerald, & Lummis, 2021). Stohlmann, Moore and Roehrig (2012) explained that teachers who have a strong understanding of STEM concepts and the ability to relate this knowledge to real life can motivate students to be more interested and engaged in STEM learning. Teacher development in STEM education can help improve teaching quality by integrating it with learning models such as inquiry-based learning (e.g. Deák, Kumar, Szabó, Nagy, & Szentesi, 2021; Conradty &

Bogner, 2019; Lai, 2018), project-based learning (e.g. Mulyopratikno & Wiyarsi, 2023; Hanif, Wijaya, & Winarno, 2019; Han, Yalvac, Capraro, & Capraro, 2015) and problem-based learning (e.g. Suciana & Sausan, 2023; Martaningsih *et al.*, 2022) that enable students to develop critical thinking, creative and problem-solving skills that are highly needed in the 21st-century workforce (Nugroho *et al.*, 2021). Teachers who are able to integrate STEM-based approaches in daily learning can also facilitate students to see the connection between theory and practical application (Hacıoğlu & Gülhan, 2021). Therefore, teachers need to continuously develop their technical and pedagogical skills, both in science teaching and in technology utilization, to prepare students for the demands of an increasingly technology-based industry (Goldsmith, Doerr, & Lewis, 2014).

The findings of this study indicate that strengthening the role of social media in STEM discourse requires a more structured and actionable strategy by policymakers, educators and educational institutions. In practical terms, educational and vocational institutions are advised to develop systematic digital interaction patterns through academic calendar-based STEM content planning, the use of interactive formats and the use of communicative approaches that encourage audience engagement. Educators need to be equipped with digital pedagogy competencies so that social media not only functions as a means of disseminating information but also as a collaborative learning space that facilitates discussion, reflection and contextual problem-solving. From a policy perspective, institutional guidelines are needed to regulate the quality standards of educational content, digital communication ethics and user data protection. In addition, strengthening collaboration between educational institutions, industry and digital media stakeholders is important to ensure the relevance of STEM content to the needs of the world of work and technological developments, so that social media can play a role as a sustainable and impactful learning ecosystem.

Conclusions

The analysis of top influencers on X reveals a diverse ecosystem of individuals, institutions and media entities dynamically advocating STEM education in Indonesia. Their collective efforts give a positive indication about the nationwide commitment to prioritizing STEM education. The findings reported that both some hashtags highlighted the importance of *guruhebat*, which is understood as excellent teachers. This shows that excellent teachers are the hope of most Indonesian people, who are voiced through social media, to become a strong Indonesia, which indicates the important role of teacher in STEM Education.

References

Adnan, M. H. M., Hassan, M. F., & Zulkefli, N. A. M. (2020). A framework of heterogeneous cloud service and multi attributes negotiation using double auction. *International Journal of Advanced Trends in Computer Science and Engineering*, *9*(3), 3961–3969. doi: 10.30534/ijatcse/2020/220932020.

Adnan, M. H. B. M., Ariffin, S. A., Hanafi, H. F., Husain, M. S., & Panessai, I. Y. (2021). A social media analytics framework to increase prospective students' interests in STEM and TVET education. *Asian Journal of University Education*, *16*(4), 82–90. doi: 10.24191/ajue.v16i4.11945.

Agussuryani, Q., Sudarmin, S., Sumarni, W., Cahyono, E., & Ellianawati, E. (2022). STEM literacy in growing vocational school student hots in science learning: A meta-analysis. *International Journal of Evaluation and Research in Education*, *11*(1), 51–60. doi: 10.11591/ijere.v11i1.21647.

Akgunduz, D. (2016). A research about the placement of the top thousand students in STEM fields in Turkey between 2000 and 2014. *Eurasia Journal of Mathematics, Science and Technology Education*, *12*(5), 1365–1377. doi: 10.12973/eurasia.2016.1518a.

Akgunduz, D., & Mesutoglu, C. (2021). Science, technology, engineering, and mathematics education for Industry 4.0 in technical and vocational high schools: Investigation of teacher professional development. *Science Education International*, *32*(2), 172–181. doi: 10.33828/sei.v32.i2.11.

Alkhammash, R. (2019). 'It is time to operate like a woman': A corpus based study of representation of women in STEM fields in social media. *International Journal of English Linguistics*, *9*(5), 217. doi: 10.5539/ijel.v9n5p217.

Amalia, D., Sutarto, J., Kurniawati, Y., & Pranoto, S. (2021). Pengaruh pembelajaran jarak jauh bermuatan steam terhadap karakter kreatif dan kemandirian. *Jurnal Pendidikan Anak Usia Dini*, *6*(3), 1233–1246. doi: 10.31004/obsesi.v6i3.1765.

Ardwiyanti, D., Prasetyo, Z. K., & Wilujeng, I. (2021). STEM research trends in Indonesia: A systematic literature review. *Journal of Science Education Research*, *5*(1), 38–45. doi: 10.21831/jser.v5i1.41752.

Baran, E., Bilici, S. C., Mesutoglu, C., & Ocak, C. (2019). The impact of an out-of-school STEM education program on students' attitudes toward STEM and STEM careers. *School Science and Mathematics*, *119*(4), 223–235. doi: 10.1111/ssm.12330.

Becker, K., & Park, K. (2011). Integrative approaches among science, technology, engineering, and mathematics (STEM) subjects on students' learning: A meta-analysis. *Journal of STEM Education: Innovations and Research*, *12*(5), 23–37.

Blömeke, S., Suhl, U., Kaiser, G., & Döhrmann, M. (2012). Family background, entry selectivity and opportunities to learn: What matters in primary teacher education? An international comparison of fifteen countries. *Teaching and Teacher Education*, *28*(1), 44–55. doi: 10.1016/j.tate.2011.08.006.

Brennan-Kemmis, R., & Green, A. (2013). Vocational education and training teachers' conceptions of their pedagogy. *International Journal of Training Research*, *11*(2), 101–121. doi: 10.5172/ijtr.2013.11.2.101.

Çevik, M. (2018). Impacts of the project based (PBL) science, technology, engineering and mathematics (STEM) education on academic achievement and career interests of vocational high school students. *Journal of Education and Instruction*, *8*(2), 281–306. doi: 10.14527/pegegog.2018.012.

Coburn, C., Russel, J. L., Kaufman, J. H., & Stein, M. K. (2012). Supporting sustainability: Teachers' advice networks and ambitious instructional reform. *American Journal of Education*, *119*(1), 137–182. doi: 10.1086/667699.

Conradty, C., & Bogner, F. X. (2019). From STEM to STEAM: Cracking the code? How creativity & motivation interacts with inquiry-based learning. *Creativity Research Journal*, *31*(3), 284–295. doi: 10.1080/10400419.2019.1641678.

Cwik, S., & Singh, C. (2021). Damage caused by societal stereotypes: Women have lower physics self-efcacy controlling for grade even in courses in which they outnumber men. *Physical Review Physics Education Research*, *17*(2), 020138. doi: 10.1103/PhysRevPhysEducRes.17.020138.

Daly, A. J. (2010). *Social network theory and educational change*. Cambridge: Harvard Education Press.

Dasgupta, N., & Stout, J. G. (2014). Girls and women in science, technology, engineering, and mathematics: STEMing the tide and broadening participation in STEM careers. *Policy Insights from the Behavioral and Brain Sciences*, *1*(1), 21–29. doi: 10.1177/2372732214549471.

Deák, C., Kumar, B., Szabó, I., Nagy, G., & Szentesi, S. (2021). Evolution of new approaches in pedagogy and STEM with inquiry-based learning and post-pandemic scenarios. *Education Sciences*, *11*(7), 319–326. doi: 10.3390/educsci11070319. Available from: https://www.mdpi.com/2227-7102/11/7/319#

Diekman, A. B., Weisgram, E. S., & Belanger, A. (2015). New routes to recruiting and retaining women in STEM: Policy implications of a communal goal congruity perspective: Communal processes in stem. *Social Issues and Policy Review*, *9*(1), 52–88. doi: 10.1111/sipr.12010.

Fisher, C. R., Thompson, C. D., & Brookes, R. H. (2020). Gender differences in the Australian undergraduate STEM student experience: A systematic review. *Higher Education Research and Development*, *39*(6), 1155–1168. doi: 10.1080/07294360.2020.1721441.

Ghani, N. A., Hamid, S., Hashem, I. A. T., & Ahmed, E. (2019). Social media big data analytics: A survey. *Computers in Human Behavior*, *101*, 417–428. doi: 10.1016/j.chb.2018.08.039.

Goldsmith, L. T., Doerr, H. M., & Lewis, C. C. (2014). Mathematics teachers' learning: A conceptual framework and synthesis of research. *Journal of Mathematics Teacher Education*, *17*(1), 5–36. doi: 10.1007/s10857-013-9245-4.

Hacıoğlu, Y., & Gülhan, F. (2021). The effects of STEM education on the students' critical thinking skills and STEM perceptions. *Journal of Education in Science Environment and health*, *7*(2), 139–155. doi: 10.21891/jeseh.771331.

Hadiyanti, N. F. D., Hobri, H., Prihandoko, A. C., Susanto, Murtikusuma, R. P., Khasanah, N., & Maharani, P. (2021). Development of mathematics e-module with STEM-collaborative project-based learning to improve mathematical literacy ability of vocational high school students. *Journal of Physics: Conference Series*, *1839*(1). doi: 10.1088/1742-6596/1839/1/012031.

Han, J., & Balabanis, G. (2024). Meta-analysis of social media influencer impact: Key antecedents and theoretical foundations. *Psychology and Marketing*, *41*(2), 394–426. doi: 10.1002/mar.21927.

Han, S., Yalvac, B., Capraro, M. M., & Capraro, R. M. (2015). In-service teachers' implementation and understanding of STEM project-based learning. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(1), 63–76. doi: 10.12973/eurasia.2015.1306a.

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing students' creativity through STEM project-based learning. *Journal of Science Learning*, *2*(2), 50–57. doi: 10.17509/jsl.v2i2.13271.

Hebebci, M. T., & Usta, E. (2022). The effects of integrated STEM education practices on problem solving skills, scientific creativity, and critical thinking dispositions. *Participatory Educational Research*, *9*(6), 358–379. doi: 10.17275/per.22.143.9.6.

Hidayati, N., & Irmawati, F. (2019). Developing digital multimedia of human anatomy and physiology material based on STEM education. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *5*(3), 497–510. doi: 10.22219/jpbi.v5i3.8584.

Kersting, N. B., Givvin, K. B., Thompson, B. J., Santagata, R., & Stigler, J. W. (2012). Measuring usable knowledge: Teachers' analyses of mathematics classroom videos predict teaching quality and student learning. *American Educational Research Journal*, *49*(3), 568–589. doi: 10.3102/0002831212437853.

Kiazai, A. N., Siddiqua, N., & Waheed, Z. (2020). Challenges in implementing STEM education and role of teacher education programs in mitigating these challenges. *International Journal of Distance Education and E-Learning*, *V*(II), 123–138.

Knaub, A. V., Henderson, C., & Fisher, K. Q. (2018). Finding the leaders: An examination of social network analysis and leadership identification in STEM education change. *International Journal of STEM Education*, *5*(26), 1–14. doi: 10.1186/s40594-018-0124-5.

Kuchynka, S. L., Gates, A. E., & Rivera, L. M. (2023). When and why is faculty mentorship effective for underrepresented students in STEM? A multicampus quasi-experiment. *Cultural Diversity and Ethnic Minority Psychology*, *31*(1), 69–75. doi: 10.1037/cdp0000596.

Kurniati, E., Suwono, H., & Ibrohim, I. (2020). Analisis profil pemahaman dan ketertarikan mahasiswa biologi pada stem education. *Jurnal Pendidikan: Teori, penelitian, dan pengembangan*, *5*(12), 1732–1737. doi: 10.17977/jptpp.v5i12.14310.

Lai, C. (2018). Using inquiry-based strategies for enhancing students' STEM education learning. *Journal of Education in Science, Environment and Health (JESEH)*, *4*(1), 110–117. doi: 10.21891/jeseh.389740.

Lu, C., So, W. W. M., Chen, Y., Wiyarsi, A., Chiu, W. K. S., Ko, Y., . . . Tho, S. W. (2024). School students' aspirations for STEM careers: The influence of self-concept, parental expectations, career outcome expectations, and perceptions of STEM professionals. *Asia Pacific Journal of Education*, 1–18. doi: 10.1080/02188791.2024.2394506.

Marsono, Khasanah, F., & Yoto (2019). Integrating STEM (science technology engineering and mathematics) education on advancing vocational student's creative thinking skills. *Advances in Social Science, Education and Humanities Research*, *242*, 170–174.

Martaningsih, S. T., Maryani, I., Prasetya, D. S., Prwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). STEM problem-based learning module: A solution to overcome elementary students' poor problem-solving skills. *Pegem Journal of Education and Instruction*, *12*(4), 340–348.

Martín-Páez, T., Aguilera, D., Jiménez-Liso, M. R., & Perales-Palacios, F. J. (2019). What are we talking about when we talk about STEM education? A review of literature. *Science Education*, *103*(4), 799–822. doi: 10.1002/sce.21522.

Misiak, M., Urbanek, A., Frackowiak, T., & Sorokowski, P. (2025). Who wants to be a YouTuber? Personality traits predict the desire to become a social media influencer. *Telematics and Informatics*, *98*, 102248. doi: 10.1016/j.tele.2025.102248.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Roehrig, G. H., Park, M. S., & Tae, J. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardella (Eds.), *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices* (pp. 35–60). Purdue University Press. doi: 10.2307/j.ctt6wq7bh.7.

Morris, J., Slater, E., Boston, J., Fitzgerald, M. T., & Lummis, G. (2021). Teachers in conversation with industry scientists: Implications for STEM education. *International Journal Innovation of Science and Mathematics Education*, *29*(1). doi: 10.30722/IJISME.29.01.004.

Morrison, J., Frost, J., Gotch, C., McDuffie, A. R., Austin, B., & French, B. (2021). Teachers' role in students' learning at a project-based STEM high school: Implications for teacher education. *International Journal of Science and Mathematics Education*, *19*(6), 1103–1123. doi: 10.1007/s10763-020-10108-3.

Moss-Racusin, C. A., Sanzari, C., Caluori, N., & Rabasco, H. (2018). Gender bias produces gender gaps in STEM engagement. *Sex Roles*, *79*(11), 651–670. doi: 10.1007/s11199-018-0902-z.

Mulyopratikno, F. W., & Wiyarsi, A. (2023). STEM-based chemistry learning in a vocational context: A study of students' chemical literacy. In *AIP Conference Proceedings*, *2556*(1), 040026. doi: 10.1063/5.0110399.

Ng, O. L., & Park, M. (2021). Using an enhanced video-engagement innovation to support STEM teachers' professional development in technology-based instruction. *Educational Technology and Society*, *24*(4), 193–204.

Nugroho, O. F., Permanasari, A., & Firman, H. (2019). The movement of STEM education in Indonesia: Science teachers' perspectives. *Jurnal Pendidikan IPA Indonesia*, *8*(3), 417–425. doi: 10.15294/jpii.v8i3.19252.

Nugroho, O. F., Permanasari, A., Firman, H., & Riandi, R. (2021). The urgency of STEM education in Indonesia. *Jurnal Penelitian dan Pembelajaran IPA*, *7*(2), 260–279. doi: 10.30870/jppi.v7i2.5979.

Nurtanto, M., Pardjono, P., Widarto, W., & Ramdani, S. D. (2020). The effect of STEM-EDP in professional learning on automotive engineering competence in vocational high school. *Journal for the Education of Gifted Young Scientists*, *8*(2), 633–649. doi: 10.17478/JEGYS.645047.

Perdana, R., Apriani, A. N., Richardo, R., Rochaendi, E., & Kusuma, C. (2021). Elementary students' attitudes towards STEM and 21st-century skills. *International Journal of Evaluation and Research in Education*, *10*(3), 1080–1088. doi: 10.11591/IJERE.V10I3.21389.

Permanasari, A., Rubini, B., & Nugroho, O. F. (2021). STEM education in Indonesia: Science teacher and students perspectives. *Journal of Innovation in Educational and Cultural Research*, *2*(1), 7–16. doi: 10.46843/jiecr.v2i1.24.

Pickering, T. A., Yuen, T. T., & Wang, T. (2016). STEM conversations in social media: Implications on STEM education. In *IEEE International Conference on Teaching, Assessment, and Learning for Engineering* (pp. 296–302).

Putri, S. U. (2019). *Pendidikan STEM: Implementasi pada pendidikan dasar.* Sumedang: UPI Sumedang Press.

Putri, C. D., Pursitasari, I. D., & Rubini, B. (2020). Problem based learning terintegrasi STEM di era pandemi covid-19 untuk meningkatkan keterampilan berpikir kritis siswa. *Jurnal IPA and Pembelajaran IPA*, *4*(2), 193–204. doi: 10.24815/jipi.v4i2.17859.

Rahmawati, A., Rizal, M. S., & Lathifah, A. S. (2021). Analisis keterampilan berpikir kritis siswa melalui pendekatan STEM (science, technology, engineering, and mathematics) dalam pembelajaran IPA. *Jurnal Tadris IPA Terpadu*, *2*(1), 15–24.

Rusydiyah, E. F., Indrawati, D., Jazil, S., Susilawati, G., & Gusniwati, G. (2021). STEM learning environment: Perceptions and implementation skills in prospective science teachers. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 138–148. doi: 10.15294/jpii.v10i1.28303.

Shaikh, B., Shinde, K., & Borde, S. (2017). Challenges of big data processing and scheduling of processes using various hadoop schedulers: A survey. *International Journal of Multifaceted and Multilingual Studies*, *3*(12), 1–6.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, *57*, 1–22.

Stieglitz, S., Mirbabaie, M., Ross, B., & Neuberger, C. (2018). Social media analytics–Challenges in topic discovery, data collection, and data preparation. *International Journal of Information Management*, *39*, 156–168. doi: 10.1016/j.ijinfomgt.2017.12.002.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for implementing integrated STEM education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *2*(1), 28–34. doi: 10.5703/1288284314653.

Suciana, D., Hartinawati, Sausan, I., & Meliza (2023). A meta-analysis study: The effect of problem-based learning integrated with STEM on learning outcomes. *European Journal of Education and Pedagogy*, *4*(2), 133–138. doi: 10.24018/ejedu.2023.4.2.619.

Suh, B., Hong, L., Pirolli, P., & Chi, E. H. (2010). Want to be retweeted? Large scale analytics on factors impacting retweet in twitter network. In *IEEE Second International Conference on Social Computing* (pp. 177–184).

Sungur Gül, K., & Ateş, H. (2023). An examination of the effect of technology-based STEM education training in the framework of technology acceptance model. *Education and Information Technologies*, *28*(7), 8761–8787. doi: 10.1007/s10639-022-11539-x.

Tan, A. L., Ong, Y. S., Ng, Y. S., & Tan, J. H. J. (2023). STEM problem solving: Inquiry, concepts, and reasoning. *Science and Education*, *32*(2), 381–397. doi: 10.1007/s11191-021-00310-2.

Widarti, H. R., Rokhim, D. A., & Syafruddin, A. B. (2020). The development of electrolysis cell teaching material based on STEM-PjBL approach assisted by learning video: A need analysis. *Jurnal Pendidikan IPA Indonesia*, *9*(3), 309–318. doi: 10.15294/jpii.v9i3.25199.

Yang, B., Zhang, R., Cheng, X., & Zhao, C. (2023). Exploring information dissemination effect on social media: An empirical investigation. *Personal and Ubiquitous Computing*, *27*(4), 1469–1482. doi: 10.1007/s00779-023-01710-7.

Zeldin, A. L., Britner, S. L., & Pajares, F. (2008). A comparative study of the self-efficacy beliefs of successful men and women in mathematics, science, and technology careers. *Journal of Research in Science Teaching*, *45*(9), 1036–1058. doi: 10.1002/tea.20195.

Zhang, A. L., & Lu, H. (2023). Scientists as influencers: The role of source identity, self-disclosure, and anti-intellectualism in science communication on social media. *Social Media+ Society*, *9*(2). doi: 10.1177/20563051231180623.

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