

Twitter-Mediated Knowledge Brokering in STEM Education Reform: A Social Network
Analysis of Key Knowledge Actors in a Mid-Sized Ontario School District During the First Year
of Reform

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Preface

My interest in the fusion of online and offline worlds was both piqued and inspired by the GameStop meme stock rise, which demonstrated the power of social media in influencing public discourse, in addition to highlighting the importance of understanding online networks and interactions. The idea for this research project later emerged from an interest in exploring the role of social media in influencing educational policy, particularly in the context of STEM education. Social media platforms have become powerful tools for connecting educators, policymakers, and the public, often shaping discussions and influencing decision-making processes. The potential of these platforms to foster knowledge diffusion and shape policy discourse is both fascinating and crucial in today's digital age.

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Abstract

This thesis examines the influence of knowledge actors in a mid-sized Ontario school district's Twitter network, with a focus on STEM-related discourse during 2019 - the year of a major Ministry reform announcement. Using social network analysis (SNA), this research investigates how different types of actors - policy, research, and practice - facilitate knowledge exchange through three analytical lenses: (1) centrality measures to identify the most influential actors, (2) strength of ties to assess cohesion within and between subgroups, and (3) structural holes to explore how brokers bridge disconnected parts of the network. Centrality measures were used to determine the top ten ranked actors, highlighting who the main categories of knowledge actors were and what role they held inside or outside the district. The combination of centrality measures allowed for the exploration of the multifaceted ways in which they exerted influence within the district's Twitter network. Two knowledge actors, a STEM teacher and a science-focused school, with high outdegree and betweenness centrality played key roles in both disseminating STEM knowledge and brokering connections across otherwise disconnected groups. These findings highlight the multifaceted influence of certain individuals, such as teachers, schools, and consultants, who acted as both visible communicators and strategic connectors within the district's Twitter network. These findings indicate that the practice subgroup had the strongest ties, facilitating a higher volume of knowledge exchange within their group. In contrast, policy actors shared a significantly lower number of tweets or mentions amongst themselves, recording only eight interactions throughout the year. The strength of ties within the science subgroup facilitated more frequent knowledge exchange about science than in any other subject matter group during the first year of the reform. In contrast, the engineering subgroup had the weakest ties, sharing the least frequently, including only one exchange with the mathematics subgroup. The analysis of structural holes revealed that a small number of knowledge brokers played a key role in bridging otherwise disconnected clusters of knowledge actors about STEM, enabling information to span boundaries across the network. This thesis contributes to understanding online educational networks at a local level, providing insight into the influence dynamics within educational policy discourse on Twitter.

Keywords: educational policy, STEM education, Twitter, social media, social network analysis (SNA), knowledge diffusion, centrality, reform

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Abbreviations

API	Application Programming Interface
CCSS	Common Core State Standards
CIS	Centre for Independent Studies
CNS	Central Nervous System
COVID-19	2019 Coronavirus Disease
CSV	Comma-Separated Values
ID	Identifier
JSON	JavaScript Object Notation
MNC	Multinational Corporation
n	Normalised
Pip	Pip Installs Packages or Pip Installs Python
PLN	Professional Learning Network
SBI	Social Brokerage Index
SCL	Sociocultural Learning
SME	Small and Medium Enterprise
SNA	Social Network Analysis
STEM	Science, Technology, Engineering, and Mathematics
USA	United States of America
USP	Universal Synthetic Phonics

Introduction

The rise of social media platforms like Twitter (now X) provides a “new” space for individuals and groups to voice their opinions and share information widely, which can influence public opinion and political discourse (Supovitz et al., 2015). Research by Daly et al. (2018, 2019) and Rehm et al. (2019) highlights the affordances of these platforms in enabling professionals, particularly in education, to build networked communities, share resources, and engage in meaningful discourse across time and space. Schuster and Kolleck (2021) emphasise the role of social media in facilitating civic engagement and public debate, particularly in policy contexts. However, these opportunities are not uniformly realised. These platforms have allowed more voices to be expressed beyond traditional media and professional advocacy groups. Daly et al. (2019) argue that:

Given the ubiquity of online activity...in our “real-world” lives, it makes increasingly less sense to think about “offline and online” worlds (Rainie and Wellman, 2011). ...in reality, the offline and online experiences just reflect a larger social continuum in which individuals interact, access resources, and make sense of their world. (p.4)

As such, social media platforms have become prominent venues for discussing policy issues and ideas, attracting the attention of researchers interested in how policy is, or can be, shaped through online activity, including whose voices are amplified within policy spaces (Barnes et al., 2023; Daly et al., 2018; Daly et al., 2019; Rehm et al., 2019; Rehm et al., 2021; Schuster & Kolleck, 2021). Policy researchers have increasingly leveraged publicly available data from platforms such as Twitter to study and interpret policy discussions and the formation of online networks. Prior to its change in ownership in 2022 and subsequent rebranding as “X,” which prompted a notable decline in user numbers and activity (Hern, 2024), Twitter had been widely recognised as a key platform for shaping public policy processes and discourse (Daly et al., 2018; Daly et al., 2019; Rehm et al., 2019; Schuster & Kolleck, 2021). It was regarded as a quick, accessible, and low-cost tool for generating knowledge flows across online networks (Daly et al., 2018).

While social media platforms like Twitter (now X) are frequently studied for their ubiquity and potential to foster connection, dialogue, and knowledge exchange, actual user engagement varies considerably. In other words, the opportunities these platforms provide are not uniformly realised. Many users primarily engage passively, by reading or scrolling, rather than actively

posting or participating in discussions. A Pew Research Center (2022) study found that nearly half of U.S. adult Twitter users post fewer than five times per month, with a small minority generating the vast majority of content. This indicates that while the infrastructure for broad participation exists, meaningful engagement is concentrated among a relatively small group of active contributors. A recent Demand Sage report (2024) observes a similar finding, suggesting that although over 40% of X's user base is active daily, only a small proportion regularly create content, while most remain passive consumers. Despite this uneven participation, educational researchers have emphasised the value of studying Twitter's role in the education sector. Scholars have explored how the platform enables access to policy networks, facilitates the formation of professional communities, and amplifies the influence of specific individuals, groups, or organisations (Barnes et al., 2023; Daly et al., 2018; Rehm et al., 2019; Schuster & Kolleyck, 2021).

The literature on social networks, including studies of social media or sub-networks within Twitter, has examined the roles of central actors, how the strength of ties between actors affects flows of knowledge in the network, and how network structures can either facilitate or constrain to and from various actors and groups, and how some actors play important roles, for example, as knowledge brokers who gatekeep or bridge gaps between distinctive or disparate groups (Barnes et al., 2023; Daly et al., 2018; Daly et al., 2019; Oliver, 2021; Rehm et al., 2019; Schuster & Kolleyck, 2021). A key focus within this body of work is the identification of knowledge brokers - actors who serve as gatekeepers or bridges between otherwise disconnected or disparate groups. Social network analysis (SNA) serves as a valuable method for mapping and analysing these relationships, offering insights into how knowledge circulates across individuals, organisations, and communities. One of the key contributions of SNA to understanding knowledge diffusion is its ability to identify central actors who serve as knowledge brokers. These individuals often have numerous connections (i.e., high degree centrality), significant influence (i.e., high eigenvector centrality), or serve as bridges or access managers between disconnected groups (i.e., high betweenness centrality), making them critical to the flow of information (Borgatti & Cross, 2003). Moreover, dynamic SNA has allowed researchers to track how knowledge flows through a network over time, shedding light on the most efficient paths, influential actors, and the speed at which information spreads (Valente, 1996).

Many researchers have used SNA to help quantify and make sense of what happens within online Twitter networks. Daly et al. (2019) described how the analytical power of SNA

“makes visible the patterns of communication in social networks that are otherwise invisible” (p. 3) to both actors interacting within the network and outside observers. SNA has become an important method for studying these interactions and key actors whilst providing insight into how social processes involved in the diffusion of knowledge could be understood across individuals and groups within social media networks, like those on Twitter. Social network studies focus on the constellations of relationships within a given network, and how those may constrain or facilitate the flow of knowledge. Previous studies have used SNA to understand network structure, influential actors, and subgroups within networks to better understand how policy can be shaped in online environments (Barnes et al. 2023; Daly et al., 2018; Daly et al., 2019; Rodway et al., 2021; Schuster and Kolleck, 2021; Supovitz et al., 2015; Supovitz et al., 2018). Using SNA, researchers have shed light on how Twitter has been (and can be) used to bring actors and organisations together in online spaces, to better understand the structure of online networks, and to identify critical, and often informal, actors in those spaces that have the potential to exert influence in ways that have not been seen before the emergence of social media platforms like Twitter (Barnes et al., 2023; Daly et al., 2018; Daly et al., 2019; Rodway et al., 2021; Schuster & Kolleck, 2021; Supovitz et al., 2015; Supovitz et al., 2018).

Online networks hold significant potential to influence local policy discourse and decision-making in education by enabling the rapid exchange of information, amplifying voices, and reshaping how educational issues are framed in the public sphere (Daly et al., 2018; Daly et al., 2019; Supovitz et al., 2015). These platforms facilitate dialogue between educators, policymakers, researchers, parents, etc., often bypassing traditional gatekeepers such as government agencies or mainstream media. As a result, Twitter can serve as a democratic space where emerging concerns can gain visibility and traction. Research has shown that social media platforms can enhance participatory policymaking by connecting grassroots voices to institutional actors. For example, Carpenter and Krutka (2014) highlighted that educators used Twitter to build professional learning networks that not only support classroom practice but also shape broader discussions on educational policy and reform. These interactions allow local education issues to be framed collectively, co-constructed through hashtags, and elevated to decision-makers who monitor or participate in these conversations. In doing so, platforms like Twitter become important venues for shaping educational agendas and influencing both the content and direction of policy discussions at the local level.

The rise of social media, and particularly Twitter, in public policy discourse and influence processes, in addition to the use of SNA to unearth and grasp such changes, serve as the foundational elements that inform this thesis. Moreover, additional inspiration for this research project was drawn from policy reform announcements in the province of Ontario. In March 2019, the Ontario Ministry of Education announced its K-12 plan to modernise learning in Ontario classrooms. The changes were proposed as a branch of the Ministry's new education vision, Education that Works for You. This included, among other things, an emphasis on learning improvement and the development of important transferable skills in several areas, including STEM fields, to improve publicly funded education in Ontario and better prepare students for future success. Over a four-year timeframe, the Ontario Ministry of Education (2019) planned to execute a \$200-million strategy to address the fundamentals of mathematics and its applications. A revised curriculum for grades 1 through 8 was implemented in September of 2020, which was designed to improve mathematics performance, everyday mathematics competence, and increase students' employability (Ontario Ministry of Education, 2020). The Ministry of Education also announced that STEM would be studied and applied in K-12 classrooms to facilitate the development of transferable skills that are understood to be critical in the contemporary global economy and society (Ontario Government, 2019). STEM initiatives were also emphasised in the technology plan of an Ontario school district wherein an investment in modern learning experiences to leverage technology as a tool that can be used to access, create, and share knowledge was highlighted (2019). These STEM reforms, both Ontario-based and within a medium-sized Ontario school district, created and helped define the boundaries for this thesis, allowing for the opportunity to leverage Twitter data and SNA to study influence and relationship dynamics within the school district.

As such, this thesis has the potential to expand a limited pool of literature, especially in Canada, by using Twitter and SNA to understand network influence, dynamics, and structure within an Ontario school district. The purpose of this thesis is to use social network analysis methods to identify the different types of actors in a school district's Twitter network and measure their influence within that network regarding STEM-related matters. As such, this thesis will be guided by three specific research objectives:

- To identify the most influential knowledge actors around STEM in the district's Twitter network during 2019, the year of the Ministry's announcement, based on relevant centrality measures.
- To investigate how the strength of ties differs within and between subgroups of those knowledge actors.
- To analyse how structural holes in the district's Twitter network influence knowledge diffusion regarding STEM

These objectives will be addressed within the context of one school district's Twittersphere in Ontario. For this research, a mid-sized school district was selected for study. The reform announcements in the province and the potential to collect a significant enough data set were sufficient for a master's-level thesis.

As technology continues to permeate our day-to-day lives, and educational stakeholders have turned to Twitter to connect, influence, and share knowledge, research efforts have begun to better understand how policy discourse and interactions occur online. As education and education adjacent actors and organisations take to Twitter to connect, share, and interact, unpacking the nature of these relationships can shine light on how their influence can be operationalised and conceptualised in a Twittersphere, especially before the platform's rebrand. Moreover, this is an opportunity to explore and identify who these actors are and how they communicate amongst themselves.

This thesis includes: a literature review, theoretical framework, methodology, results and findings, and a discussion and conclusion. The literature review highlights the policy, Twitter-, and/or SNA-based studies that were used to inform and ground the approaches taken in this thesis. The theoretical framework underlines the types of knowledge actors and how centrality is used to understand knowledge diffusion and the network's characteristics. The methodology section provides an overview of research design and method, the egocentric network analysis approach taken to analyse the data, the software used (UCINET), data collection (web scraping Twitter), and the approach that was taken to categorising the groups of actors in the thesis. The findings provide insight into who the central actors were in the network, who were influential based on the different centrality measures used, the tie strength within and across the different categories of actors, and how structural holes contributed to the facilitation or constraint of knowledge flow throughout the network. Finally, the discussion and conclusion highlight how

the results are similar and different from other work done to further contextualise the findings, discuss the broader implications of this type of research, and shed light on the thesis's limitations, in addition to future research that can be done, especially with Twitter's recent rebrand.

Literature Review

In recent years, educational policy discourse has increasingly unfolded across both traditional offline venues, such as legislatures, conferences, and school corridors, and the fast-moving online platforms like Twitter. These online platforms have become important arenas for the exchange of ideas, the dissemination of research, and the negotiation of policy discourse. Knowledge rarely influences policies or practices on its own; it needs knowledge brokers who can translate ideas and research findings, weave them together, communicate them to disparate actors, and keep knowledge flowing across different groups in policy conversations. Instead, they require the work of knowledge brokers - individuals or organisations who translate, contextualise, and circulate information across diverse communities.

Knowledge brokering has become as an important concept in educational policy research, particularly in studies that examine how ideas move between research, practice, and policymaking. Brokers play a central role in shaping discourse, building coalitions, and ensuring that knowledge reaches relevant audiences. At the same time, a growing body of research has turned attention to the role of social media in educational policy, with platforms like Twitter (now X) serving as dynamic spaces for public engagement, professional learning, and policy advocacy. Within these “Twitterspheres,” knowledge brokers continue to play a vital role - amplifying research, connecting disparate groups, and shaping the visibility of particular ideas or actors. Social network analysis (SNA) offers a systematic way to identify these brokers by mapping who exchanges information with whom, highlighting actors in central or bridging positions that afford them disproportionate leverage in mobilising knowledge.

This chapter situates the thesis within these two bodies of literature: (1) the literature on knowledge brokering and social network analysis in policy networks, and (2) the literature on social media as a site of policy discussion and influence. Together, these perspectives provide a conceptual and methodological foundation for analysing how influence and information flow through digital educational networks. In other words, by integrating insights from both the knowledge brokering and social media literatures, this thesis examines how STEM-related knowledge was shared and brokered within a mid-sized Ontario school district’s Twitter network during the first year of a reform.

Knowledge Brokering in Policy Networks

This section analyses three recent studies by Oliver (2021), Rodway et al. (2021), and Weber & Yanovitzky (2021), each of which applies social network analysis to identify knowledge brokers in policy-related networks and how they influence the flow of knowledge in those networks. Across the studies, attention shifts from formal roles to relational positions, such as hubs and bridge-spanning brokers, whose well-placed connections between various actors carry advice, resources, and research evidence. Mapping these connections reveals that influence in networks often rests not with titleholders but with actors who cultivate high-quality links and accurately read their networks. The three studies that follow illustrate these applications of SNA concepts to generate empirical insights (see Table 1).

Table 1. *A summary of the three studies used to understand knowledge brokering and its influence in policy networks*

Study	Context	Objective	Key Concepts	Method	Findings
Oliver, K. (2021). “Being important” or “Knowing the Important”: who is best placed to influence policy?. Networks, Knowledge Brokers, and the Public Policymaking Process, 49-69	United Kingdom in a public health policy network across ten local authorities	Explore how researchers can identify influential actors within policy networks to effectively influence policy and practice	Knowledge brokering: Facilitating transfer, translation, application of knowledge (research evidence) between researchers and decision-makers Power: A resource (authority, expertise) and a relational force enacted in social interactions Influence: Ability to affect agendas, decisions, outcomes Authorities: Actors widely recognised as powerful or influential in the network Hubs: Actors skilled at understanding the network, identifying and connecting key actors in it Structural holes: Actors gain influence by bridging disconnected parts of the	Instruments : <i>Survey:</i> Network members asked to nominate influential, powerful actors and sources of evidence for public health policymaking <i>Interviews:</i> Network members asked about reasons for nominations, definitions of power and influence, and perceptions of influential actors Participants : 152 individuals working in public health policy	Characteristics of powerful, influential actors (Authorities) : Senior executives; some mid-level managers also wielded influence by coordinating meetings and linking groups Characteristics of actors skilled at identifying influential actors (Hubs): Tended to be mid-level managers who excelled at identifying key network actors and building relationships in the network; their role based on positive reputation rather than formal authority or job title

Study	Context	Objective	Key Concepts	Method	Findings
			network, acting as gatekeepers or brokers of knowledge		
Rodway, J., MacGregor, S., Daly, A., Liou, Y. H., Yonezawa, S., & Pollock, M. (2021). A network case of knowledge brokering. <i>Journal of Professional Capital and Community</i> , 6(2), 148-163.	Four large school districts in southern California	Three research questions: (1) What are the patterns of knowledge exchange within this PLN? (2) Who are the knowledge brokers? (3) What are the implications of brokering on knowledge mobilisation?	Knowledge brokering: About “knowledge flow” and the individuals who mobilise knowledge within a community or a network (p.149)” Network activity: Interactions and exchanges of knowledge within a social network, encompassing direct and indirect ties Direct ties: Immediate connections actors have in the network, measured by degree centrality Indirect ties: Connections mediated by other actors that facilitate flow of knowledge, measured by betweenness centrality	Instruments : <i>Social network survey:</i> Mapped the interactions among teachers, school leaders, and instructional coaches	Understanding the network structure: Advice-seeking was the most connected type of tie, indicating that most staff exchanged teaching advice with at least two colleagues. Other types of ties (new ideas, differentiation, and materials) averaged fewer than two connections
Weber, M. S., & Yanovitzky,	No geographic region	Explore the role of knowledge	Knowledge brokering: Iterative	Instruments :	Brokers have an impact:

Study	Context	Objective	Key Concepts	Method	Findings
I. (2021). Knowledge brokers, networks, and the policymaking process. In M. S. Weber & I. Yanovitzky (Eds.), <i>Networks, knowledge brokers, and the public policymaking process</i> (pp. 1–30). Springer Nature Switzerland AG	specified; examines knowledge brokerage across various policy domains (health, education, communication) and contexts (local, state, national, international)	brokerage in influencing public policymaking and practice through a review of empirical studies	translation and exchange of research evidence to inform practitioners, policymakers Knowledge brokers: Actors who are intermediaries to facilitate the exchange of knowledge between disconnected actors, bridging gaps (structural holes) in policy networks Use of research evidence: The process of acquiring, understanding, and applying research evidence in policy and practice Policy ecosystem: Complex network of interconnected actors - policymakers, advocates, researchers, journalists, and citizens - interacting to shape and enact policy	<i>Structured network surveys:</i> That ask name-generator or ego-network questions to map who exchanges knowledge (research evidence) with whom <i>Mixed-methods instruments:</i> Such as interview protocols or administrative network data to validate brokerage roles and influence pathways	- Actors in bridging positions (high betweenness) consistently channel knowledge and shape policy - e.g., two-thirds of teachers lacked research access unless connected to such brokers. - Brokering is a position and an activity: Effective brokers linked disconnected parties through their positioning in the network, while using that position to raise awareness, make evidence usable, and mobilise stakeholders

Oliver (2021) investigated how to identify influential actors within organisations, focusing on those who could help shape policy and/or practice. She approached her study by identifying key players to better understand the constellations of relationships which underpin policy. She used the concepts of Hubs (actors who know everyone) and Authorities (actors who everyone thinks are important) to see who was good at identifying influential actors, whether any of those actors were also important, and how individuals exert power. She concluded that power is not always tied to a formal position; it can arise from personal skills, reputation, and one's ability to build and/or exploit relationships. Participants whose perception of their own network was the most accurate were a better source of power. Hubs tended to be more influential despite lacking what might be considered formal authority; it is these types of actors that others should focus on connecting with instead of targeting those with authority (Oliver, 2021). The findings also demonstrated the overlapping roles of hubs and authorities, and the ways in which they used strategies like controlling decision-making organisations, managing policymakers, and leveraging network structures to exert influence. This study, thus, highlighted the importance of relational skills, network perception, and strategic connections in influencing policy, suggesting that researchers should prioritise engaging with Hubs over traditional Authorities. Oliver (2021) cautioned on potential biases, such as recall bias and missing data, which may affect the accuracy of network analyses. Additionally, she raised the question of the subjective nature of influence and power definitions that came to pose conceptual and methodological challenges in her study.

Rodway et al. (2021) explored how to effectively understand knowledge brokering within organisations by considering both direct and indirect network interactions. Direct network interactions focused on more immediate connections and exchanges made by network actors (e.g., an instructional coach brokering resources). Indirect network interactions captured less obvious interactions, such as a classroom teacher who may not play a formal brokering role but still plays a significant role in resource exchange (Rodway et al., 2021). Their study used social network theory to analyse knowledge brokering as a function of network activity and utility, with a case study focused on improving mathematics instruction. Interactions were mapped according to four instrumental relations: advice-seeking, new ideas, differentiation, and materials. They found that, overtime, there was improved connectivity and access to resources; at the beginning, advice-seeking had the highest centrality, but by the end of the project, centrality and density for

all relational dimensions significantly increased (Rodway et al., 2021). The network's structure and the roles of knowledge brokers evolved, highlighting the importance of direct and indirect interactions. Moreover, the increase over time in the interconnectedness of the entire network enhanced the capacity for knowledge sharing and resource mobilisation. This study demonstrated that it is not only traditional, authoritative actors, like instructional coaches, who can fill certain types of roles; when provided the opportunity, non-traditional actors, such as classroom teachers, can play a critical role in the brokering of knowledge and resources. This work also emphasised the importance of strong ties, and that any brokering role is fundamentally relational and can be most effective when actors adaptively engage within their evolving social environments (Rodway et al., 2021).

Weber and Yanovitzky (2021) observed that viewing knowledge brokerage through a social network lens shifts attention from the traits of would-be experts to the relational architecture that channels knowledge, such as research evidence, in policy “ecosystems” or networks. In their work, social network analysis helped identify who was connected to whom, and where gaps existed in the structure of relationships constituting the network. Centrality measures, such as degree, betweenness, and eigenvector can quantify an actor's reach, gatekeeping capacity, and influence. Such actors provided others with “opportunities” to have their knowledge brokered across a policy network's busiest corridors. Additionally, structural hole indices complemented centrality measures by measuring the extent to which an actor bridged with otherwise disconnected clusters of other actors. Actors that act as brokers have an informational advantage and strategic control over how, when, and to whom knowledge circulate. By combining these indicators, social network analysts can move beyond anecdotal lists of “key stakeholders” to evidence-based identification of brokers and rigorous assessment of the leverage they exercise in the flow of knowledge in policy ecosystems. Weber and Yanovitzky (2021) stressed how this enables researchers to mobilise findings and evidence in policy ecosystems, and to design interventions that strengthen or redistribute brokerage roles so that research knowledge flows to the important actors and groups.

Twitter and Social Network Analysis in Educational Policy Research

Previous studies have demonstrated how studying Twitter, especially through an SNA lens, has allowed researchers to identify influential actors in online networks, understand network structure, and highlight subcategories of actors that tend to emerge in online educational

policy studies. The foundation of this work as it pertains to Twitter can be illustrated through five key studies in education, all of which were used to demonstrate how researchers employed different methodological approaches to study and examine Twitter-driven data.

Pulling from educational policy, social network analysis, and/or Twitter studies was essential to inform this thesis as it provided a comprehensive framework for understanding policy discourse, influence dynamics, and knowledge exchange in online spaces. When this study was conducted, few studies existed in the literature that effectively pulled from all those bodies of literature; therefore, this study is anchored in relevant education studies that were able to fuse policy, SNA, and/or Twitter to look at influence and knowledge diffusion within a school district's Twitter network. Educational policy research offers insights into how policy ideas evolve, who shapes them, and the mechanisms through which they are implemented. Social network analysis enables the mapping of influence, power, and knowledge diffusion, revealing hidden interactions and the role of key actors in shaping policy discussions. Studies on Twitter and other online platforms highlight how policy debates unfold in real-time, how diverse voices engage, and how online spaces can facilitate and/or distort public discourse. These fields collectively illuminate how influence can be exerted, how policy narratives are constructed, and how online communication strategies can be leveraged to shape public opinion and policy outcome.

Table 2. *A summary of the five studies used to guide Twitter-focused work in this study*

Study	Context	Objective	Key Concepts	Method	Findings
Daly, A. J., del Fresno, M., & Supovitz, J. A. (2018). <i>The Social Side of Educational Policy: How Social Media is Changing the Politics of Education</i> . Teachers College Record, 121 (14), 1-26.	USA on the Twitter network about Common Core State Standards (CCSS)	Explore how social media transforms the production, dissemination, and consumption of information and the strategies used by advocacy groups to influence public opinion	Structural social capital: the network of social relationships surrounding an individual or group; the connections, ties, and interactions that provide opportunities for resource exchange and collaboration Homophily: the tendency of individuals to associate and form connections with others who share similar characteristics, preferences, or worldviews	Instruments: <i>Twitter Network Data Collection:</i> nearly 1 million tweets sent over 32 months (spanning 2.5 years) by approximately 190,000 distinct <i>Twitter users:</i> -Used hashtags related to the Common Core, such as #commoncore, #ccss, and #stopcommoncore	Influence Beyond Follower Count: - While the number of followers is often used as a measure of influence, findings show that influence is also determined by the structure and quality of relationships within social networks - Some actors held significant influence not because of their follower count but due to their strategic connections and ability to amplify messages effectively Types of Influential Actors: - Influential actors include transmitters, transceivers, and transcenders, who play key roles in spreading ideas and shaping opinions within networks. - These individuals leverage their relationships and interactions to move messages and access resources
Daly, A. J., Supovitz, J.,	USA	Examine the role of	Impact of a Twitter	Instruments: Twitter	- Social media has altered how hidden

Study	Context	Objective	Key Concepts	Method	Findings
& Fresno, M. D. (2019). The social side of educational policy: How social media is changing the politics of education. <i>Teachers College Record</i> , 121(14), 1–26.		Twitter in shaping discourse around policy for CCSS	Impact of a Twitter network re: how knowledge is shared and with whom to make invisible interactions and connections visible	Instruments: <i>Twitter Data:</i> Focused on CCSS hashtags, and analysed approximately 1 million tweets across 2.5 years <i>Network Analysis:</i> To visualise and identify patterns in how actors were connected and how messages spread <i>Linguistic Coding:</i> To assess how language, frames, and metaphors were used to advance political messages	- Social media has altered how hidden networks of actors can shape / influence policy discourse - Influential actors are not always the most followed but are strategic in their use of Twitter - Online social networks can be exploited for political purposes (e.g., botnets) and can induce “echo chambers”
Rehm, M., Cornelissen, F., Notten, A., Daly, A., & Supovitz, J. (2019). Power to the people?! Twitter discussions on (educational	Netherlands	Investigate whether Twitter conversations around #onderwijs2032 have the potential to contribute to / impact policy process	Application of Nahapiet & Ghoshal’s (1998) framework (structural, cognitive, and relational dimensions): To examine how social media fosters	Instruments: <i>Twitter Data Analysis:</i> From hashtag #onderwijs2032, collected over ~4 months <i>Semi-Structured Interviews:</i> Conducted interviews	- Network structure featured active central users, isolated participants, and subclusters that interacted more within themselves than with the larger group. - Four social roles (social hub, social authority, social organiser,

Study	Context	Objective	Key Concepts	Method	Findings
) policy processes (pp. 231–244).			resource exchange, shared understanding, and trust among education stakeholders Role of Twitter in policy discourse: To investigate how educators and professionals used Twitter to participate in and potentially influence a national curriculum review Informal and networked governance: To link findings to theories of network governance, emphasising horizontal, participatory policy dynamics Influence and brokerage: Created SBI to classify	with central actors in the network to explore motivations, strategies, and perceived impact of participants in the Twitter debate <i>Bibliometric Analysis:</i> To identify key themes in tweets and analyse language patterns and discourse across different types of users	social influencer) were identified that actors could play

Study	Context	Objective	Key Concepts	Method	Findings
			users' roles based on their influence and behaviour		
Schuster, J., & Kolley, N. (2021). Education in times of global crisis: How private actors in Germany gain power through Twitter. Education Policy Analysis Archives, 29, 161.	Germany on the Twitter network about the digital learning and homeschooling solutions	Examine the different actors' influence re: digitisation in schools in Germany during COVID-19 pandemic	Policy networks: To emphasise that education policy is shaped not only by formal governmental actors but by interdependent networks of both state and non-state actors Social network theory: To analyse relationships and information flow on Twitter, wherein influence is inferred from an actor's network position (centrality) and their ability to connect others, rather than just formal authority	Instruments: <i>Twitter Network Data Collection:</i> 7,426 tweets and 18,824 retweets, all published during the period from March 8 to March 23, 2020 (seven days before and six days after the school closures on March 16). <i>Participants:</i> Accounts were categorised into groups such as teachers, experts/consultants, SMEs, MNEs, government, and non-profits based on publicly available information (e.g., biographies,	- Four types of influential actors were identified - individual experts and consultants, SMEs, multinational corporations, and public sector actors - Web links in tweets highlighted digital learning platforms and frequently referenced corporations like YouTube

Study	Context	Objective	Key Concepts	Method	Findings
			Influence and private actor visibility: Ability of experts, consultants, MNEs, and SMEs to use Twitter to promote products, platforms, and expertise Twitter as a policy arena: How Twitter serves as a forum for influence, where different actor groups promoted agendas, built networks, and shaped public policy Information inventors: Those who generate new content and share resources Information spreaders: Those who amplify others' content through mentions and retweets	blogs, websites)	

Study	Context	Objective	Key Concepts	Method	Findings
Barnes, N., Watson, S., & MacRae, S. (2023). The moral positioning of education policy publics: How social media is used to wedge an issue. <i>Critical Studies in Education</i> , 64(4), 337–354.	Australia	Explore how social media is used by think tanks to create “wedge issues” in public policy	Rooted in Luhmann’s theory of moral communication , which centres on how morality functions as a mechanism of social inclusion/exclusion, marking behaviours as good or bad, which can polarise discourse by limiting open discussion	Instruments: <i>NVivo12</i> : used for qualitative content analysis <i>Twitter search</i> : tweets collected using key words and hashtags Participants: public Twitter accounts of anyone engaging in the online debate (e.g., parents, teachers, unions, politicians)	- Conservative think tanks use social media to influence public opinion and promote divisive issues aligned with their views. - They rely on clickbait and emotional content to boost message virality. - One case study showed their use of the Overton Window to shift views on higher education, while another highlighted algorithmic tactics used to amplify their reach

Twitter as a Vehicle for Knowledge Brokering and Influence in Educational Policy

Before rebranding, Twitter was a microblogging social media platform where users could write and share short messages, called tweets, that were up to 280 characters and could be shared with their entire online network. A tweet could be posted from any device and could contain images, URLs, hashtags, and videos (Twitter, 2019). As of 2025, the character limits for posts on X differ based on a user's subscription level. Standard, or “free” users, can post content up to 280 characters in length, which includes all text, spaces, emojis, and links; however, X users who subscribe to the “premium” service are permitted to post messages up to 25,000 characters long (X, 2025a). Additionally, media attachments such as images, videos, and GIFs do not count toward the character limit. Usernames that appear automatically at the beginning of replies are also excluded from the count, and manually typed @mentions within the body of the post are included (X, 2025b). These updated limitations are part of X’s broader strategy to balance concise communication with the ability to share richer content, especially for users subscribing to its premium services.

However, before the rebrand, through different features and functions, all Twitter users could share knowledge throughout their network and the networks of others. Twitter was becoming widely adopted and embraced across educational contexts, and studies highlighted its use in classrooms, learning, motivation and engagement, teaching, auxiliary support, professional development and networking, social endeavours, communities of practice, conferences, and information sharing (Malik et al., 2019). Twitter was free and prevalent across the globe, which allowed its users to connect, interact, and share knowledge with one another in real-time about any subject (Weller et al., 2013). Jack Dorsey, Twitter’s founder, went so far as to describe Twitter as the CNS (central nervous system) of the Internet (2012). Previous Twitter studies in educational policy have suggested that the two key uses for Twitter include knowledge sharing and exerting online influence (Barnes et al., 2023; Daly et al., 2018; Daly et al., 2019; Rehm et al., 2021; Schuster and Kollect, 2021).

Research on Twitter Networks and Educational Policy

Daly et al.’s (2018) study of the Common Core State Standards (CCSS) debate on Twitter played a key role in demonstrating how social media was transforming political discourse, in that case in the USA. The analysis of Twitter discussions around the hashtag #CommonCore demonstrated how a network analysis of a social media platform could reveal

key actors driving conversations to influence policymaking. Daly et al.'s (2018) analysis of Twitter discussions around CCSS revealed three distinct subgroups with varying opinions regarding the policy, and their differences in network reach - that is, who was most able to reach vast portion of the network to influence discussions. As a result of their work, Daly et al. (2018) were able to highlight that certain actors from these subgroups were more influential than others. One subgroup of high-activity actors, referred to as "superhubs," had the ability to reach 94% or more of the network, depending on the centrality measure used (Daly et al., 2018). The strong, interconnected CCSS social network on Twitter significantly influenced discussions and effectively spread information and ideas across the platform. Daly et al.'s work demonstrated the ability that social media, especially Twitter, had in shifting and shaping political discourse. This shift introduced a new body of literature which necessitated a deeper understanding of how social networks operate to influence public opinion. Daly et al. (2019) highlighted that not attending to this space, the role of social media in politics and educational policy, would be a wasted opportunity for research, practice, and policy makers.

Although the first large-scale example of actors congregating in an online space to share knowledge and attempt to influence other actors was the policy debate around CCSS (Daly et al., 2018), other research has since demonstrated similar findings in education - that discussions online can gain enough attention to influence offline policy processes and discussions. After their 2018 study, Daly et al.'s (2019) did further research that highlighted a dramatic transformation in which information is produced and published in contemporary society, naming Twitter as a platform used by all types of actors to address others and share knowledge. Their work also shed light on the benefits of strategic relationships when it comes to wielding influence, outside of one's follower count, highlighting the used of social-media-enabled strategies (e.g., botnets, the retweet function, hashtag campaigns), which can be used to disseminate knowledge and influence actors in these online spaces, including around reshaping policy discourse and debates. When it comes to influence, actors in social media spaces can be intentional and strategic about how they connect and manage their networks to gain influence and reach broader audiences (Daly et al., 2019). This work was a key example which underscored the importance and relevance of not only online Twitter discussions in real-world policymaking but also the benefit of leveraging social media savviness, including the technical knowledge of how to use social media, to expand one's reach and exert influence.

Rehm et al.'s (2019) work provided insights that could help policymakers better understand how discussions on Twitter evolved, and how online network actors could leverage the platform for more dynamic and inclusive policy processes, demonstrating Twitter's ability to facilitate knowledge exchange, help build connections among educators, and its role in shaping policy. The objective of their study was to understand how Twitter discussions contributed to social capital formation among educators discussing educational policy within the context of the Dutch initiative #onderswijs2032 (#Education2032). They found that Twitter discussions facilitated the exchange of knowledge and connections among network actors, which enhanced social capital. Discussions were broken down into topics that were frequently discussed by actors. Researchers wanted to understand which actors made knowledge sharing contributions. Many actors reported a sense of urgency to share around the hashtag to make their voices heard with the potential of influencing the policy process (Rehm et al., 2019). Rehm et al. stressed that Twitter was crucial when it came to providing a space for actors to participate in and influence discussions, share knowledge, and connect with others regarding the policy. This was especially important for teachers who were often excluded from policy-making spaces; Twitter provided a platform for their voices to be heard, in addition to strategies they could employ to be listened to, calling attention to the space that Twitter created for those outside of traditional policy-making environments to share knowledge in hopes of influencing change. Insights from this work were helpful for policymakers who wished to better grasp how discussions evolved in online forums to shape and influence policy in the real-world. These researchers' work also provided a roadmap for more informal actors, such as teachers, to become more involved in processes that have the potential to influence and shape policy discourse.

Schuster and Kolleck (2021) leveraged Twitter data to demonstrate how private actors in Germany took advantage of social-media-enabled communication to gain power through online means in the discussion about homeschooling and the digitisation of education during the COVID-19 pandemic. Germany was used as a case study to underline the need for digital learning solutions during what was described as a low level of pre-pandemic digitisation. The pandemic amplified discussions and interactions on Twitter about homeschooling and educational digitisation. Schuster and Kolleck found that before the pandemic, the most central actors in the Twitter network were mostly teachers and school leaders, many of whom shared their experiences in the field; however, following school closures in response to the pandemic,

small and medium enterprises (SMEs) increased their Twitter presence to showcase their digital learning solutions to expand their influence through the provision of support for students, families, and educators who were being asked to rapidly change their practises and expectations in response to the COVID-19 pandemic in the name of expanding their influence. Multinational corporations (MNCs) were not as active in discussions, but were frequently referenced, via mentions, by others in the network, using the COVID-19 crisis to expand their own market presence and influence by organically benefitting from others talking about them during the pandemic. Similarly, non-profit organisations emerged as critical players in these discussions, sharing information and networking online, with some of their projects initiated as a response to the pandemic (Schuster & Kolleck, 2021). As the pandemic forced school closures in Germany, Schuster and Kolleck's research underlined a shift in influence around policy discussions and who the central actors were in this network, with SMEs and non-profits prominently and promptly establishing themselves as influential players. Schuster and Kolleck's work highlighted the opportunity that informal actors (e.g., non-profits, SMEs, MNCs) were given in shaping and influencing education and practice on a large scale, with all discussions beginning on Twitter. Their work highlighted the increasing integration through online means of private or non-traditional actors in policy debates and spaces, and the potential for their roles in and strategic use of these spaces to continue growing.

Barnes et al. (2023) examined how two think tanks in Australia strategically leveraged social media, versus traditional media, for lobbying purposes. Their work found that think tanks could reach a broad audience when employing specific, strategic techniques (e.g., emotive or provocative headlines), highlighting social media's role in being able to influence public opinion. Their second case study shed light on the formation of highly interconnected online networks that are formed to help facilitate widespread dissemination of a group's viewpoint, which demonstrates an actor or group's ability to shape any type of discourse and strategically use social media to influence policy debates (Barnes et al., 2023). Barnes et al. zeroed in on the exploitation of social media's "moral communication" possibilities to shape public opinion, with the potential of influencing policy outcomes, which underscores the evolving role of "new media" in educational policy discourse. The authors concluded that the communication techniques used by think tanks in their study were instrumental in shaping educational policy debates and influencing public perceptions, which impacted policy processes. This finding is

crucial for policymakers and others engaging in Twitter conversations, as it points to the need for social media savviness in navigating the platform and using strategies to shape narratives and discussions. Moreover, these authors' work provided insights around how social media could be used to manipulate and influence its users into falling in line with certain opinions or processes.

Twitter studies in educational policy have demonstrated that social networks are not passive or peripheral structures; they are active systems that can be leveraged into offline discourse and manipulated by the actors that interact within them. It is the dynamic interplay that exists between an actor's actions and the network's structure that allows researchers to delve deeper into how knowledge spreads and who emerges as influential. This is particularly interesting for: (1) individuals looking to have their voice heard online in a way that can be influential; and (2) for policymakers seeking to better understand how offline and online dialogue around policy discussions have the potential to merge.

Measuring Influence in Knowledge Brokerage Using SNA Centrality Metrics

As the previous sections underscored, numerous researchers have used SNA centrality measures to describe and analyse the roles of influential knowledge actors, such as knowledge brokers, in educational policy discussions in both off and online networks, including on Twitter (Barnes et al., 2023; Daly et al., 2018, 2019; Oliver, 2021; Rehm et al., 2019, Rodway et al., 2021; Schuster & Kolleck, 2021; Weber & Yanovitzky, 2021). What follows is a summary of the various SNA centrality measures used and the insights they provided.

Use of Centrality Measures in Offline Policy Networks

Oliver's 2021 analysis of a public health policy network comprising 225 actors employed a range of eigenvector-based centrality measures, centring on Kleinberg's Hubs and Authorities model. Each actor was assigned an authority score, indicating the extent to which they were recognised by others as powerful or influential, alongside a corresponding hub score, which identified individuals proficient at recognising such authorities. This methodology effectively differentiates between actors who are widely regarded as influential (Authorities) and those who are particularly skilled at identifying influential individuals (Hubs). Oliver supplemented this analysis by using degree centrality metrics to help identify actors in structurally advantageous knowledge brokering positions. Together, this mix of authority, hub, and conventional centrality measures allowed Oliver to pinpoint not only the actors who commanded attention (authorities)

but also the mid-level managers who, through accurate mental maps of the network, quietly orchestrated information flow and policy influence (hubs).

Oliver (2021) drew on survey and interview data and employed a Hubs and Authorities analysis. Hubs and Authorities analysis is derived from eigenvector centrality, which captures a person's importance in terms of how well connected they are to other important people (Borgatti et al., 2013). It is used to distinguish between actors who are influential (Authorities) and actors who know a lot of others in the network (Hubs). Oliver concluded that, although Authorities were typically identified as critical players in a network when using standard centrality measures, it was the Hubs that tended to be the most influential in this study because they were better connected within the network. This held true even though actors who were categorised as Hubs did not necessarily hold a formal position within the organisation like an Authority would. Moreover, she reported that the most effective influencers in the network were those who were considered both Hubs and Authorities as they held formal positions and were also well connected to others (Oliver, 2021).

Rodway et al. (2021) relied on two standard centrality measures to identify knowledge brokerage in a professional learning network in education. They used indegree centrality to measure how often a staff member was named as a source of knowledge resources (e.g., via advice, ideas, materials, or specific teaching strategies), and outdegree centrality as an indicator of the direct exchange of knowledge by those who routinely supplied such resources to colleagues. The authors also used betweenness centrality to measure indirect knowledge brokering by actors who lay on the shortest paths between otherwise disconnected peers. Such actors brokered knowledge across structural gaps in the network. Together, this mix of degree and betweenness centrality measures revealed that several classroom teachers, and not just the official instructional coaches, became the network's most active knowledge brokers over time. For Rodway et al., this demonstrated how actors working in everyday positions could position themselves to have policy-relevant influence.

Weber and Yanovitzky (2021) synthesised other empirical studies to illustrate and explain how centrality metrics help define network characteristics and identify actors in knowledge brokering roles. They treated centrality metrics as the starting point for mapping how knowledge travels in policy-relevant networks, noting that degree, betweenness, and eigenvector centrality measures allow researchers to see whether a network actor is well connected (degree),

acts as a shortest path between otherwise separate groups (betweenness), or occupies a prestigious position (eigenvector) that can broadcast ideas widely. One study they cited highlighted that educators connected to highly central colleagues enjoyed better access to research evidence, shedding light on how the central connectors could boost the entire network's ability to engage with that type of knowledge.

Use of Centrality Metrics in Studies of Social Media

Daly et al. (2018) analysed Twitter data (183, 346 tweets), which was collected over a six-month period based on discussions around the hashtags #CommonCore or #Common Core. The key centrality measures used were indegree centrality (incoming ties/mentions) and outdegree centrality (outgoing ties/retweets). The study focused on the top 1% and 0.25% of users based on outdegree and indegree activity. For the top 1% analysis, they found that eighteen superhub nodes could reach 94.5% of the network (indegree/mentions), and nineteen superhub nodes could reach 95% of the network (outdegree/retweets), which indicated influence over information flow and the spread of information, respectively. Using degree centrality analysis (indegree and outdegree) demonstrated that a small number of actors (the superhubs) had significant influence because they were able to substantially affect the flow and exchange of ideas and information in the network (Daly et al., 2018, 2019). This study emphasised the importance of being highly active and popular within a network, highlighting how actors with several mentions and retweets were able to reach more actors in the network than their less popular and active counterparts.

Similarly, Rehm et al. (2019) used degree centrality measures to analyse Twitter-based discussions around the Twitter hashtag #onderwijs2032, an education initiative in the Netherlands, to examine whether and how actors' participation contributed to the formation of structural social capital. In their study, SNA was used for macro-level analysis to map the network's structure, identify participating actors, and what roles they played in sharing knowledge. In so doing, Rehm et al. relied on degree centrality metrics to calculate three measures for every Twitter user in the #onderwijs2032 debate: indegree (times others mentioned/replied to the user), outdegree (times the user mentioned/replied to others), and total degree (their sum). From the raw data, they developed a Social Brokerage Index (SBI) that allowed for the categorisation of network actors whose total degree score was above the network mean into four knowledge brokering roles. These included: (1) social hubs (actors contacted by

many for contributions, but who did not always engage in replies); (2) social authorities (actors who shared valuable knowledge in a widespread manner and engaged in discussions by frequently mentioning and responding to others); (3) social influencers (actors who shared opinions actively and engaged in discussions via frequent mentioning and replying); and, (4) social organisers (actors similar to influencers but more frequently active in important discussions and who maintained a dedicated presence in online spaces). Based on their findings, Rehm et al. argued that by sharing knowledge in Twitter discussions, numerous actors within the network were able to contribute to their own and others' social capital.

Schuster and Kolleck (2021) employed in- and outdegree centrality to better understand the influence of multinational corporations, non-profits, and SMEs around digital learning and homeschooling during the COVID-19 pandemic. MNCs were frequently referenced via mentions (indegree centrality), despite being more peripheral within the network, indicating high popularity. This means that their platforms and products were often mentioned and central in conversations. Non-profits also became more central after school closures by leaning on platforms like Twitter to share information and establish networks (outdegree centrality), helping them grow their influence in educational policy. Schuster and Kolleck (2021) observed that actors with fewer followers also mentioned accounts with large followings to reach a broader audience, which highlighted the importance of high-profile accounts when it came to amplifying knowledge related to digital learning and homeschooling. The authors also used betweenness centrality to identify key knowledge brokers in the network discussion. They found that non-profit organisations and multinational corporations emerged as entities with high betweenness centrality, meaning these organisational actors played significant roles in connecting various parts of the network. Multinational corporations did this through frequent mentions and links to their products and platforms, and non-profits used their central roles to share information to help influence the debate. Other accounts with high betweenness centrality (e.g., governmental bodies) were also seen as influential hubs that could help spread information more widely.

Barnes et al. (2023) examined 2,150 tweets around the #phonics debate hashtag on Twitter, which was focused on whether to support universal synthetic phonics (USP). In contrast to the use of centrality measures reported in the preceding studies, in this case, the authors visualised the tweets in SNA software (Gephi with a Force-Atlas 2 layout) and treated the resulting visual map as an interpretation of centrality. The software algorithm automatically

pulled densely connected Twitter accounts to the middle of the image and pushed sparsely linked ones to the edge. Barnes et al. interpreted actors that appeared at the hub of the graph as the network's key knowledge brokers, while peripheral actors or those with one-way ties signalled limited centrality within the network. The authors inferred high degree and brokerage potential from an actor's spatial prominence and the tangle of reciprocal ties around it, rather than computing separate degree, betweenness, or eigenvector scores. Their approach used the visual centre-periphery logic of the layout, and the qualitative contrast between multi-directional versus mono-directional link patterns, to identify influential hubs and bridges without resorting to formal centrality statistics. Through this approach, they found that supporters of sociocultural learning (SCL) had mostly one-directional ties with little engagement and/or sharing. In contrast, those supporting USP were characterised as having multidirectional communication. One such actor was the Centre for Independent Studies, which in offline contexts, appeared to be peripheral in debates but upon closer analysis was found to play a significant role in brokering knowledge online.

Calls for Further Research

As shown throughout this literature review, there are two distinct bodies of literature that have been combined to shed light on knowledge brokering in networks and the role of social media. The first body of literature focused on the role of knowledge brokers in policy networks in the real world. Researchers such as Oliver (2021), Rodway et al. (2021), and Weber & Yanovitzky (2021) explored how knowledge brokers facilitated the exchange and mobilisation of research-based knowledge among various actors within the education system. This body of literature demonstrates the importance of knowledge brokers as they can bridge the gap between policy, research, and practice, ensuring that evidence-based insights are integrated into policy discussions and decision-making processes. By understanding the network structures and identifying key actors, policymakers can enhance the flow of knowledge and foster a culture of research use within the policy networks.

The second body of literature aims to explore how platforms like Twitter are used to shape, influence, or communicate public policy. They investigate how actors (e.g., policymakers, educators, activists) use social media to engage in policy discourse. Researchers such as Barnes et al. (2023), Daly et al. (2018, 2019), del Fresno García et al. (2016), Liou et al. (2015), Rehm et al. (2019), and Schuster & Kolley (2021) have called for more work and research into the

mechanisms by which social media affects policy discussions and (re)interpretation. These studies have shown how Twitter and other platforms are increasingly used as spaces for policy discourse, where educators, policymakers, and the public engage in real-time discussions about reforms and initiatives. However, this body of literature remains relatively limited. This is especially true in Canadian landscapes where there is limited research highlighting the potential for system and non-system actors to partake in and influence policy discussions, especially surrounding STEM policy reforms.

As scholars continue to advocate for further investigation into the influence and potential of social media, particularly Twitter, on policy (Barnes et al., 2023; Daly et al., 2018; Daly et al., 2019; del Fresno García et al., 2016; Liou et al., 2015; Rehm et al., 2019; Schuster & Kolleck, 2021), it is increasingly important to conduct research that enhances our understanding of how to identify influential actors, such as knowledge brokers, within networks; how network structure shapes the flow of knowledge; and how various subgroups emerge within these networks. This study sought to describe and analyse one ego-network, specifically, the Twitter network of a single district, to identify key actors or organisations that disseminated and facilitated the exchange of different forms of knowledge (i.e., STEM, science, technology, engineering, and mathematics) among research, policy actors, and practice actors during the first year of a STEM reform. By integrating insights from both strands of literature, this work aims to address existing gaps in each and contribute to the advancement of both research domains.

Theoretical Framework

This thesis is nested at the intersection of the fields of educational policy, social media, and social network analysis. It was designed to explore the role of knowledge actors using social media to diffuse knowledge regarding STEM in a school district's Twitter network during the first year of a related reform in 2019. The goal was to identify the most influential actors in the network to better understand whose STEM knowledge in the district's Twitter's network. This allowed for the analysis of the patterns of interactions among the different types of actors conveying different types of STEM knowledge on Twitter.

The Dynamic Nature of the Activity in the Twitter Network

Daly et al. (2019) define network activity as the observable interactions and exchanges between actors within a Twitter network. They emphasise that network activity reflects the dynamic, real-time behaviour of actors in order to understand how influence and information circulate in online networks. These authors use mentions, replies, and retweets as indicators of engagement. Schuster and Kelleck (2021) focus on network activity as the frequency and direction of interactions among users in Twitter-based policy debates. Drawing on social network theory's emphasis on interactional ties (Borgatti et al., 2013), this study conceptualises ties not simply as indicators of formal association (i.e., follower/following relationships), but as expressions of active knowledge exchange and influence. In line with this perspective, network dynamic activities are defined through observed interactions, specifically retweets and mentions, which signal intentional engagement between actors within the network.

While earlier studies (e.g., Rehm et al., 2019) often relied on static representations of network structure, using Twitter's API to collect follower/following data as proxies for social ties among actors (Mitchell, 2018), this thesis adopts a more dynamic, activity-based perspective aligned with recent scholarship (e.g., Schuster & Kelleck, 2021). Rather than treating social ties among actors as fixed indicators of affiliation, this approach conceptualises them as active, directed expressions of engagement and knowledge exchange, constructed through retweet and mention data. In other words, these interactions among different actors are understood not merely as a following-follower, but as intentional acts of knowledge exchange that reflect the temporal and purposive nature of social ties in the Twitter network.

As Schuster and Kolleck (2021) noted, each retweet or mention constitutes a new instance of relational intent, signalling influence, attention, or alignment, unlike follower relationships, which may be passive. This theoretical framing also resonates with Daly et al. (2018), who emphasise that knowledge sharing in online networks is driven by repeated, active engagement rather than static affiliation. Accordingly, the focus of the thesis was on capturing patterns of knowledge diffusion and influence among actors interacting within and around the district's STEM-related discussions. This approach permitted the inclusion of influential actors who may not have formal follower/following ties with the district but who nonetheless played a significant role in the dynamic dissemination of knowledge via mentions and retweets. Approaching this work through a dynamic, interaction-focused lens, allowed for the theorisation of the school district's Twitter network not just as a structural artefact, but as an emergent, evolving system of knowledge exchange, shaped by active participation over the course of the year. This framing enabled an approach that went beyond static measures of relationships to better reflect the dynamic processes of influence and knowledge exchange within the district's Twittersphere.

The Types of Knowledge Actors and their Centrality in the Twitter Network

To examine how STEM knowledge was diffused during the first year of the reform in one district's Twitter network, three categories of actors who were likely to share knowledge around STEM were identified: research, practice, and policy knowledge actors. Research actors comprise university-based researchers who produce knowledge (e.g., ideas, theories, explanations, materials) for teachers to use to inform or improve educational practice, training, and policy implementation (Honig, 2004; Tseng, 2012). Practice actors designated teachers and school principals for whom knowledge resides in their professional practice and experience. Practice actors' knowledge consists of ideas, tools, and materials created from their teaching practice and the professional learning associated with it (Datnow & Park, 2010). Policy actors can be understood as traditional actors who work within school districts on policy-related matters (e.g., trustees, superintendents) (Cooper, 2013; Honig, 2004), and diverse nontraditional actors (e.g., parents, private organisations, advocacy groups) operating through networks to challenge institutions and promote different knowledge about educational policy (Daly et al., 2019; Oliver, 2021). In this study, knowledge is defined as any information that originates from sources of

research, practice, or policy (Datnow and Park, 2010), and the categories of knowledge actors were based on the biographies (descriptions) associated with the actors' Twitter accounts.

Three centrality measures allowed for additional insight into which individual actors or organisations were influential or central in the school district's Twitter network: degree centrality (in- and outdegree centrality), betweenness centrality, and eigenvector centrality. Degree centrality, a measure of popularity and high activity, designated the number of ties or connections an actor or organisation had to others in a network. The more connections an actor had, the better their chances of accessing knowledge and resources through their connections, as well as to disseminate knowledge more expansively (Borgatti et al., 2013; Crossley et al., 2015). Betweenness centrality, a measure of knowledge brokerage, suggests that an actor or organisation can bridge gaps between groups of actors or organisations that would otherwise be disconnected within a network. The broker's role helps facilitate the flow of knowledge between different groups with different ideas (del Fresno García, 2016; Kolleck, 2016; Liou & Daly, 2020). Eigenvector centrality, a measure of prestige, indicates an actor's importance by considering the importance of their connections (Golbeck, 2013). In the context of this study, high eigenvector centrality reflects that actors are well-connected to others who themselves hold influential positions within the network, as evidenced by their high degree centrality (both indegree and outdegree) and/or high betweenness centrality. Using this measure, it is possible to see that even an actor with few connections can be prestigious if they are connected to others in a network that are well-connected themselves (Golbeck, 2013; Hansen et al., 2011).

To examine the diffusion of STEM knowledge during the first year of the reform within the district's Twitter network, theories of knowledge brokering and social network influence were drawn upon to guide the identification and operationalisation of key actors. Building on the conceptualisations of Honig (2004) and Tseng (2012), it was theorised that knowledge in educational policy networks is shared from three primary sources: research actors, practice actors, and policy actors. Research actors, who are typically university-based, produce formal knowledge, including theories, frameworks, and materials, intended to inform teaching practice and policy implementation. Practice actors, comprising teachers, educational specialists, principals, etc., possess knowledge rooted in their experiential practice and ongoing professional learning (Datnow & Park, 2010). Policy actors encompass both traditional institutional actors (e.g., trustees, superintendents) and nontraditional participants (e.g., parents, private

organisations, advocacy groups) who mobilise different forms of knowledge to influence educational governance and reform efforts (Cooper, 2013; Daly et al., 2019; Oliver, 2021).

In this thesis, knowledge is conceptualised as information produced through research, practice, or policy engagement (Datnow & Park, 2010), and actor categorisation was based on the biographical descriptions provided on each actor's Twitter account. This approach reflects assumptions from theorising in the field of knowledge brokering wherein different types of actors contribute distinct forms of expertise to reform conversations, and that understanding these contributions is essential to mapping how knowledge circulates within educational networks. To investigate influence and knowledge diffusion within the network, three key centrality measures from social network analysis were employed, each tied to distinct theoretical constructs of network dynamics.

Degree centrality captures network activity and popularity; actors with higher degree centrality are theoretically better positioned to access and spread resources, enhancing their capacity for knowledge mobilisation (Borgatti et al., 2013; Crossley et al., 2015). Betweenness centrality reflects the concept of brokerage, theorised as the ability to connect otherwise disparate groups, thereby facilitating the transfer of knowledge across structural gaps (del Fresno García, 2016; Kolleck, 2016; Liou & Daly, 2020). Eigenvector centrality measures prestige and embedded influence within the network, grounded in theories of power diffusion - actors are influential not simply by the volume of their connections, but by being connected to other highly influential actors (Golbeck, 2013; Hansen et al., 2011). In combination, these measures provide a theoretically informed framework to analyse how different types of actors, with varying forms of knowledge, participate in and shape the networked processes of STEM reform discourse. The analytical focus was not simply descriptive but rooted in theories of knowledge diffusion and brokerage within dynamic policy networks.

Network Characteristics

To understand the STEM network and the knowledge diffusing through it, a structural approach was also used when describing and analysing the configuration of relationships among the three types of knowledge actors and the subject matter being addressed (Brass, 2022). This allowed for the visualisation of the district's Twitter network structure during the first year of the STEM reform in 2019.

How the Strength of Ties is Conducive to Knowledge Brokering

In social network theory, the strength or weakness of a tie between actors significantly influences how knowledge is accessed, diffused, and adopted (Coleman, Katz, & Menzel, 1957; Granovetter, 1973). Granovetter's theory of the "strength of weak ties" posits that weak ties, connections between individuals who interact infrequently or are not closely connected, are especially valuable for accessing nonredundant information and novel resources. These ties often serve as bridges across subgroups, enabling knowledge brokers to connect otherwise disconnected parts of a network (Brass, 2022; Tasselli et al., 2020). In this thesis, tie strength is understood through the frequency of observable interactions - specifically, the number of mentions, tweets, and retweets exchanged between an account and the district's Twitter account. For example, frequent exchanges between the district and another account suggest a strong tie, indicative of ongoing collaboration or shared practice. In contrast, weak ties, characterised by infrequent or one-off interactions, may signal bridging connections to actors outside the district's core network, who nonetheless be beneficial in introducing new ideas or perspectives. this study sought to examine the strength of ties among the categories of actors within the school district's Twitter network.

How Structural Holes Facilitate Knowledge Brokerage and Opportunities in Policy

Building on Burt's theory of structural holes, network characteristics derive their value-potential from the gaps or missing connections between individuals or groups within a network (Burt, 1992). By examining the structural arrangement of relationships, it is possible to observe the opportunities and constraints that structural holes, or gaps, between disconnected individuals or groups create (Borgatti and Halgin, 2011; Burt, 2000; Crossley et al., 2015; Kolleck, 2016; Liou et al., 2015). This means that when an individual, known as the ego, which in this study is the district's Twitter account, has connections to two or more individuals who are not connected to each other, a structural hole exists. These holes represent opportunities for the ego or other individuals to bridge connections and act as brokers between disconnected individuals or groups in the network (Tasselli et al., 2020). These structural holes provide the ego access to diverse, nonredundant information and resources, access to diverse perspectives, ability to control the flow of knowledge, and potentially gain power and influence within the network (Brass, 2022; Tasselli et al., 2020). This concept is often contrasted with the idea of densely connected

networks, wherein individuals are connected to each other and can provide other benefits such as trust, reciprocity, and the monitoring of behaviour (Brass, 2022).

Brokers, whether they are the ego or other actors, play an important role because they serve as bridges between subgroups of actors to connect and share new knowledge, resources, and/or ideas from other subgroups of actors that would otherwise be disconnected (Burt, 1992; Crossley et al., 2015). In a Twitter network, this means that an actor or organisation that retweets or shares tweets with different categories of actors serves as a bridge between these subgroups. The broker's role can increase an actor's social influence as they find themselves in a unique position in the network where they are able to connect with different groups or types of actors. This translates to them being able to control the types of knowledge flowing through the network. They can subsequently determine whether that knowledge is going to be (re)shared, with whom it might be (re)shared, etc.; thus, the structural position within a network determines one's ability to exert influence within that network (Borgatti & Halgin, 2011; Kolleck, 2016).

Methodology

Research Design and Method

To examine how STEM knowledge was disseminated during the year of the reform announcement (i.e., 2019) from the Ministry within a district's Twitter network, a quantitative approach was employed to capture retweets and mentions in Twitter discussions for three key reasons. First, social network analysis enabled the identification of influential knowledge actors based on exchanges of retweets and mentions. This represented an individual-level perspective, facilitating an understanding of the influence of individual nodes (e.g., people, organisations) within the network via centrality measures. Second, it allowed for the capture of social ties among different knowledge actors and the strength of those ties. This was framed as a subgroup-level perspective, examining the extent to which Twitter exchanges (e.g., retweets, mentions) among the same categories of knowledge actors were weak or strong. Third, social network analysis made it possible to explore the underlying structural activity patterns among distinct categories of knowledge actors (structural dimensions). This reflected a macro-level perspective, enabling the mapping of the Twitter network's overall structure, as well as the configuration of relationships among the three types of knowledge actors and the subject matter discussed throughout 2019 (Brass, 2022).

In the field of educational policy, recent studies have concentrated on individuals' attributes, formal positions, or other outcome measures to analyse the networks of interactions in which they are embedded, and which influence their access to policy ideas, resources, and/or knowledge (Daly et al., 2018; Schuster and Kolleck, 2021). The methodological approach adopted in this thesis aligned with established practices in the social network analysis of Twitter data within educational policy research. Specifically, previous studies have similarly employed network analyses, utilised centrality measures (e.g., indegree, outdegree, betweenness, eigenvector) to identify influential actors, and focused on interactions such as mentions and retweets to trace the diffusion of knowledge and influence (Daly et al., 2018; Schuster and Kolleck, 2021). This informed the decision to map network structures and to identify key actors based on their ties within the district's Twitter network.

An Egocentric Approach

An ego-network (ego-net) approach focuses on the network surrounding an individual or organisation (Crossley et al., 2015; Tasselli et al., 2020). It comprises the immediate connections

and relationships that an individual or organisation maintains with others, typically including family members, friends, colleagues, and acquaintances. An ego-network concentrates on the direct ties and interactions that an individual has, providing insights into the structure, composition, and dynamics of their social relationships (Tasselli et al., 2020). This thesis adopted an ego-network approach to capture the ties between a selected school district's Twitter account and various categories of knowledge actors engaged in exchanges, mentions, and retweets related to STEM within the network. The selected ego was a mid-sized, urban school district in Ontario.

Methodological Advantages and Limitations

The ego-network approach offers several advantages that make it particularly well-suited for analysing social media interactions in educational contexts. This approach also enabled the analysis and visualisation of the Twitter network's structure, highlighting the existing ties both among the categories of actors and with the district's account. It was examined to gain a deeper understanding of the Twitter-based social media interactions and connections between the school district and other actors, as well as among the actors themselves, that had the potential to exert influence. A thorough examination of the school district's network structure facilitated a more nuanced understanding of what online Twitter activity (e.g., mentioning, retweeting) and interactions signify, and how these specific Twitter functions could be reconceptualised as forms of online influence measurable through social network analysis measures.

While the ego-network approach offers valuable insights into the structure and dynamics of social media interactions, it also presents some methodological limitations. First, the choice of Twitter as the main platform does not capture the full range of the school district's knowledge exchanges or influence across other platforms or in offline contexts. This means that findings are context-specific and may not be generalisable to other school districts or educational settings with different characteristics. Second, the ego-network approach is inherently time-bound and context specific. The data represents a specific period and may not reflect long-term trends in the patterns of interaction among these actors or the evolving knowledge exchange over time. In addition, not all Twitter interactions signify meaningful relationships among the actors. For instance, a retweet may not imply endorsement or influence, complicating the interpretation of the ties.

Twitter Data and the Categories of Knowledge Actors

Twitter served as the sole data source for this thesis. The Twitter data were categorised according to disciplinary parameters (e.g., STEM, science, technology, engineering, mathematics) during the web-scraping process. All tweets containing specific STEM subject matter disciplines, either directly or via hashtags (e.g., #STEM), were extracted using the command line. For the purposes of this project, STEM tweets were defined as any tweets, retweets, mentions, and related activities that included references to STEM, science, technology, engineering, or mathematics. The specific content of the tweets was not analysed, as content analysis fell outside the scope of this research. Instead, this project focused on categorising tweets by STEM discipline and identifying the type of knowledge actor; the tweets themselves were not examined in detail. Tweets predominantly consisted of retweets and mentions, most of which involved the school district. If an actor or organisation tweeted about multiple STEM disciplines, they were categorised according to the discipline they referenced most frequently. For instance, if an account tweeted about science seven times and engineering three times, they were classified as a science actor.

A pilot approach for identifying the types of knowledge actors was undertaken prior to the official data collection process. This preliminary scrape was solely intended to support the development of reliable and consistent coding for the three categories of actors before assembling the final dataset. During this phase, Web Scraper, a free web-scraping extension for Google Chrome, was installed and used to extract a small sample of knowledge actors from the school district's Twitter network. Web Scraper features a point-and-click interface, allowing users to interact with the software by selecting visual elements, and can be easily configured through pre-made selectors to specify the data to be extracted. To gain a basic overview of the different actors related to STEM operating within the school district's Twitter network, the target handle (i.e., @schooldistrict) and the required data (i.e., the school district's followers and their biographies) were selected based on pre-defined STEM criteria. From this preliminary web scrape, three categories of knowledge actors were identified: practice, research, and policy actors. These categories were determined and coded based on the actors' Twitter biographies. During the formal data collection phase, a more sophisticated web-scraping tool was employed to extract data from the school district's Twitter page.

Study Timeline and Data Collection

To collect the data, Twitter was web-scraped to obtain information relating to STEM from the school district's Twitter account between January and December 2019 (inclusive). All tweets posted between January 1st, 2019, and December 31st, 2019, were extracted. Initially, tweets from seven days before and after the Ministry's announcement were scraped to analyse whether the announcement had significantly altered Twitter activity and interactions during that period. The data collected during this initial phase proved limited; therefore, the decision was made to scrape and analyse tweets from the entirety of 2019 to better capture the school district's Twitter network over the full course of the year.

Web scraping can be defined as the practice of gathering data by means other than a programme interacting with an API (Application Programming Interface) or a human using a web browser (Mitchell, 2018). This is achieved by writing an automated programme or using a specific command line that queries a web server, requests data, and parses that data to extract the required information based on parameters specified in the command line. During the web-scraping process, coding was undertaken to include specific parameters to retrieve STEM-specific data from Twitter. The keywords used to scrape STEM-related content were STEM, science, technology, engineering, and mathematics. Consequently, there is a possibility that some STEM-related content and/or accounts active in STEM discussions were missed during the data collection process. As previously noted, the content of the tweets was not analysed; rather, the focus was on categorising tweets according to their STEM subject matter to better understand patterns of influence within the school district's Twitter network.

The data collection process was conducted using Terminal, the terminal emulator available within the macOS operating system. The process began by installing pip, a package management system used to install and manage software packages, and configuring twarc (twarc2), a command-line tool and Python library designed for collecting and archiving Twitter JSON data via the Twitter API. The API key and secret keys, used for authentication to ensure secure access between different software systems and APIs, were then inputted. A Twitter developer account was obtained, which provided the necessary tokens and keys to access the school district's Twitter data for academic research purposes.

The categories of actors were identified by establishing specific parameters within the command line. The command was used to run the Python script ten times - once for each

instance of tweets related to STEM subject matter either received by or sent out from the school district. All actors and organisations included in the thesis were classified as knowledge actors, as they were directly scraped from the school district's Twitter account using command lines specifically designed to retrieve accounts tweeting about STEM subjects. Accounts were excluded if data were missing or incomplete (e.g., the account lacked a biography or other information required for categorisation purposes). Only accounts that interacted with the school district in relation to STEM topics were included; accounts outside of these interactions would not have been extracted during the web-scraping process. Furthermore, only accounts active within the school district's Twitter network during 2019 were retained for analysis. As all data were collected from publicly available Twitter content, the thesis did not involve direct data collection from human participants and thus did not require approval from the University's Research Ethics Board.

As the content of the tweets was beyond the scope of this project, it is possible that some tweets were scraped more than once if they contained references to multiple disciplines. During the conversion of the scraped Twitter data from JSON to CSV format, approximately 10% of the data were lost. Data loss and distortion are typical during conversion processes, due to structural differences between JSON and CSV data formats (Mitchell, 2018). This loss equated to around 25 actors and 75 tweets that were not included in the final dataset. Consequently, some Twitter accounts were excluded, particularly those lacking the necessary data for categorisation or for the data analysis process.

To retrieve the Twitter data, the platform's API was accessed to collect tweets, user profile information, discussions, and related content (del Fresno García et al., 2016; Moukarzel et al., 2020; Rehm et al., 2021; Schuster and Kolley, 2021). Python was then used to send basic commands to retrieve all STEM-related tweets associated with the school district throughout 2019. Web scraping enabled the selective extraction of the school district's Twitter data and the identification of influential categories of actors within the district's network, using keywords such as STEM subject matter, district identifiers, directionality (to or from), and date ranges.

The data collected focused on direct interactions through mentions or retweets, representing active exchanges or expressions of interest between accounts, rather than the more static mapping of an ego-network based on follower relationships (Crossley et al., 2015). Accordingly, dynamic information (e.g., mentions and retweets) was extracted to create an edge

list, mapping the sources (those mentioning or retweeting) and the targets (the accounts mentioned or retweeted). As the aim was to examine an ego-network structured around types of knowledge actors, only tweets containing at least one form of interaction (i.e., a mention or retweet) involving the school district were included in the social network analysis.

Data Analysis

UCINET, a software package for the analysis of social network data, was used to analyse the ego-network data (Borgatti et al., 2002; Crossley et al., 2015). The data were organised within UCINET's in-house matrix, which enabled the importation, management, analysis, and visualisation of the network data (Borgatti et al., 2002). Within UCINET, the 'Matrix Editor' was used to create a blank spreadsheet, into which network values (i.e., nodes and the valued ties between them) were imported by copying and pasting from an Excel file (.xlsx) into the UCINET database. This formed the node dataset, or relational dataset, depicting the relationships between all nodes in the Twitter network.

An attribute dataset was also uploaded, which included each node's ID and its attributes, specifically, the STEM subject matter discipline and the category of actor to which it belonged (e.g., practice, policy, or research). Numerical values were assigned to both actor categories (1 for practice, 2 for policy, 3 for research) and STEM disciplines (1 for STEM, 2 for science, 3 for technology, 4 for engineering, 5 for mathematics). Coding in UCINET is carried out using numerical values to ensure consistency and computational efficiency, simplifying data handling and allowing the software to process matrices and perform calculations such as centrality measures (Borgatti et al., 2002). This standardised numerical approach helps minimise errors and ensures consistent interpretation of the data across analyses. In preparation, dimensions were created within the Matrix Editor to account for the 284 actors identified in the Twitter network. Labels were assigned to each node using predetermined IDs (e.g., 1, 2, 3), and all knowledge actors were allocated attributes (e.g., subject matter, actor category) to enable clear distinction between them. The network data were then organised by pasting all network actors, including the school district's Twitter account, along both the X and Y axes.

The analysis first examined degree (indegree and outdegree), eigenvector, and Freeman's betweenness centrality measures for all knowledge actors. These measures were employed to assess and determine which actors were most influential in diffusing knowledge about STEM within the network structure. Schuster and Kolleck (2021) similarly used centrality measures to

identify influential actors in social media discourse by computing centrality values for mentions within a Twitter network, based on the assumption that mentions require deliberate action by the sender and, therefore, represent a stronger form of interaction. Furthermore, by calculating ingoing and outgoing tweets (i.e., indegree and outdegree centrality), it is possible to explore the popularity, activity, and authority of specific actors within the network - factors that can be interpreted as indicators of influence. Closeness centrality was not included in the final analysis, as the results were insignificant; there were no meaningful differences among actors, and no individual actor was closer to others than the rest of the network, making it an ineffective measure of influence in this context of this thesis. To ensure comparability across networks of different sizes and structures, centrality measure values were normalised by dividing each actor's score by the maximum possible score within the network. Normalisation transformed raw centrality values into a standardised range, typically between 0 and 1, allowing for meaningful comparisons between actors and across different contexts (Wasserman & Faust, 1994; Borgatti et al., 2013). This approach was taken to help prevent the misinterpretation of results that could arise from variations in network size or density. Normalising the data enhanced the reliability and validity of the analysis, aligning with best practices recommended in social network analysis research.

The next step involved computing the densities, or average strength of ties, within and between groups, categorised by subject matter and by type of actor. To measure the strength of ties, values were first attributed to the existing relationships between the school district and knowledge actors. Previous research has highlighted the benefits of both strong and weak ties within networks. For instance, Schuster and Kolleck (2021) demonstrated that weak ties played a crucial role in promoting the digital learning agenda during the COVID-19 crisis, as they helped bridge diverse groups and facilitated the spread of educational resources and policy debates beyond close-knit subgroups. Similarly, Rodway et al. (2021) showed that strong ties contribute to stable and efficient knowledge exchange over time, supporting resource mobilisation and strengthening knowledge brokering across networks.

In this thesis, values were assigned based on the number of interactions (i.e., tweets, retweets, mentions) a knowledge actor had with the school district (ego) or with other actors within the network. For example, if Actor A tweeted at the school district eight times, this interaction would be assigned a value of eight; if the school district retweeted Actor A twice, it

would be assigned a value of two. Where no interactions occurred between two actors (across the X and Y axes), the value was recorded as zero.

An egocentric analysis was then conducted to visualise the network through a graphical representation of the school district's Twitter network. This visualisation depicted the structural arrangements and configuration of relationships within the district's Twitter network, focusing on STEM interactions among the three categories of actors and by subject matter during 2019.

Findings

This section presents the findings in four parts. First, the composition of the district's Twitter network is described, including its overall size and the number of actors within each distinct category. Second, the results of the individual-level analysis are presented, highlighting the most influential actors within the district's Twitter network based on the centrality measures employed. Third, the findings from the subgroup-level analysis are discussed, focusing on the strength of ties within and across subject matter groups and actor categories, with particular attention to the frequency of interactions. Finally, the ego-network level of analysis is presented, providing a visualisation of the district's Twitter network structure and illustrating its role in the sharing, or brokering, of STEM education knowledge across the three categories of actors and by subject matter.

Description of the District's Twitter Network

The school district's Twitter network comprised 284 actors, including the school district itself (the ego), and 363 ties (edges). Across 2019, the network generated 897 tweets related to STEM (i.e., STEM, science, technology, engineering, or mathematics), of which 543 were directed to or through the school district, and 354 occurred between other actors within the network. The network's density value was 0.005, indicating a low-density, or sparse, network - one characterised by limited interconnectedness among its actors.

Table 3. *A breakdown of the practice-, policy-, and research-based actors based on the five subject matter categories during the 2019 year*

Subject Matter	Number of Actors from District
STEM	70
Science	85
Technology	17
Engineering	8
Mathematics	103

Table 3 presents a breakdown of the number of actors within each category in the Twitter network. A total of 283 accounts constituted the network, representing all three categories of actors (practice, policy, and research) active on Twitter during the 2019 year. The distribution of actors by subject matter was as follows: 36.4% mathematics, 30% science, 24.7% STEM, 6% technology, and 2.8% engineering. Overall, 91.1% of all actors associated with STEM (across all subject matter categories) were concentrated within the disciplines of STEM, science, or mathematics.

Table 4. *A breakdown of the category of actors in the school district's Twitter network throughout the 2019 year*

Category	Number of Actors in each Category
Practice	193
Policy	80
Research	10

Table 4 breaks down the network's actors by the pre-identified actor category to which they belonged. In total, there were 283 actors, all of whom fell into one of the three categories. 68,2% were practice actors, 27,3% were policy actors, and 3,4% were research actors. As such, practice-oriented actors made up the majority of the district's Twitter network, with research-oriented actors having the least representation during the 2019 year. The network comprised 284 actors including the school district.

Table 5. *A breakdown of the Twitter network's tweets by STEM discipline*

Subject Matter	Number of Tweets (to and from)
STEM	117
Science	301
Technology	67
Engineering	19
Mathematics	393

The data presented in Table 5 shows the breakdown of tweets within the network. In total, 897 tweets were exchanged among the three categories of actors and the school district, all relating to STEM education in some capacity over the course of 2019. Of these, 43.8% pertained to mathematics, 33.6% to science, 33.5% to STEM, 7% to technology, and 2% to engineering. Thus, most interactions within the network focused on mathematics and science, while engineering had the least representation in STEM-related interactions.

The Type of Actors and Their Influence in the School District's Twitter Network

This section presents the ten most influential accounts based on each selected centrality measure. The top ten accounts were chosen because, beyond this point (e.g., after the tenth most influential actor), the results showed that accounts had minimal to no influence when assessed across the various centrality measures, with values either at or close to zero. This is partly attributable to the network's low density. As previously mentioned, all values were normalised to ensure fair comparisons. Normalisation involved standardising the data format to facilitate analysis and allow for clearer identification and interpretation of even minor differences between

values (Borgatti et al., 2013). Normalised values are indicated by ‘n’ (e.g., nbetweenness centrality).

Each table is divided into five columns. The first column lists the ID of the individual account; the second column identifies the category of actor (e.g., practice, policy, research); the third column provides more specific details about the type of actor or organisation; the fourth column indicates the main subject matter the actor tweeted about (e.g., STEM, science, technology, engineering, or mathematics); and the final column presents the actor’s influence value within the network, calculated for each specific centrality measure used to assess influence within the school district’s Twitter network.

Degree Centrality - Indegree and Outdegree

Table 6. *The number of incoming tweets or mentions from the three categories of actors*

nIndegree				
ID	Category of Actor	Specific Actor or Organisation	Subject Matter	Value
26	Practice	Teacher	STEM	0.004
11	Practice	School	Science	0.001
128	Practice	School	Science	0.001
12	Practice	School	Science	0.001
86	Practice	School	Science	0.001
3	Practice	Instructional technology consultant	Mathematics	0.001
25	Practice	School	Mathematics	0.001
27	Practice	Teacher	Mathematics	0.001
35	Practice	School	STEM	0.001
18	Practice	School	Mathematics	0.001

Indegree Centrality

Table 6 provides a breakdown of actors according to indegree centrality, which reflects incoming tweets, whether mentions, shares, or retweets, related to the diffusion of STEM knowledge. The findings reveal that the top ten most influential knowledge actors in the district's Twitter network during the first year of the STEM reform were practice actors. Knowledge actors with high indegree centrality received the most attention, both through sharing their own tweets and being shared by others, thereby gaining greater visibility compared to policy actors or research actors. This suggests that the dissemination of STEM knowledge was primarily driven by those directly engaged in educational practice.

Among these practice actors, three types of knowledge actors were identified: two teachers, seven schools, and one instructional technology consultant. The highest-ranked knowledge actor was a STEM teacher (ID 26, teacher, STEM). This teacher's high indegree centrality indicated a key position of influence within the district's network, receiving the most attention from others. Seven of the ten most influential actors were schools, highlighting that schools, as a category of practice actors, attracted significant attention through tweets and mentions, likely from other knowledge actors seeking educational resources, policies, and best practices.

The presence of one influential instructional technology consultant (ID 3) suggests that their expertise was highly sought after, particularly by actors seeking specific advice, support, and information related to mathematics. Much of the attention in the network focused on science and mathematics, indicating that interdisciplinary STEM education or other topics such as technology and engineering were less prominently discussed during this initial year of reform.

Outdegree Centrality

Table 7 presents the breakdown of outdegree centrality, reflecting the number of outgoing tweets, retweets, and/or mentions sent by an actor to another actor within the network and/or the school district. The findings show that the top ten most influential knowledge actors in the district's Twitter network during the first year of the STEM reform were practice actors, along with one policy actor. Knowledge actors with high outdegree centrality were those who sent the most tweets, mentions, or retweets, making them more active in the creation and dissemination of knowledge than research or other policy actors. Knowledge production and

diffusion were therefore primarily driven by individuals directly engaged in educational practice, alongside one actor involved in policy advocacy.

Table 7. *The number of (re)tweets or mentions the district sent*

nOutdegree				
ID	Category of Actor	Specific Actor or Organisation	Subject Matter	Value
118	Practice	Teacher	Science	0.004
3	Practice	Instructional technology consultant	Mathematics	0.001
4	Practice	Teacher	Technology	0.001
80	Practice	School	Mathematics	0.001
5	Practice	Instructional coach	Science	0.000
12	Practice	Teacher	Science	0.000
67	Practice	School	Science	0.000
10	Policy	Education network	STEM	0.000
20	Practice	Teacher	STEM	0.000
52	Practice	Teacher	Science	0.000

Among these practice actors, three types of knowledge actors were represented: four teachers, two specialists (an instructional technology consultant and an instructional coach), and one school. The policy actor identified was an educational network. The highest-ranked knowledge actor was a STEM teacher (ID 118, teacher, STEM). This teacher's high outdegree centrality indicated a key role in the district network by actively sending the most tweets and mentions. One instructional coach (ID 5) was also identified as an influential practice actor, suggesting that, in this role, they frequently sent tweets and mentions offering advice, support,

and information particularly related to science. The repeated appearance of the instructional technology consultant (ID 3) across both the indegree and outdegree centrality rankings indicates that this specialist in mathematics not only received significant attention but also actively engaged with others in the network by sending and sharing tweets. Most knowledge tweeted and shared related to science, mathematics, technology, and STEM more broadly, suggesting that these four subject areas were actively diffused by influential actors. In contrast, engineering was not widely shared during this first year of reform.

Betweenness Centrality

Table 8. *Degree to which the categories of actors stand between each other and/or the district*

nBetweenness Centrality				
ID	Category of Actor	Specific Actor or Organisation	Subject Matter	Value
118	Practice	Teacher	Science	1.833
2	Policy	Blood service organisation	STEM	1.624
4	Practice	Teacher	Technology	0.799
5	Practice	Instructional coach	Science	0.784
3	Practice	Instructional technology consultant	Mathematics	0.762
138	Policy	Advocacy organisation	STEM	0.650
128	Practice	School	Science	0.413
7	Policy	Superintendent	Science	0.385
137	Research	University	STEM	0.352
11	Practice	School	Science	0.348

The highest-ranked actor was a STEM teacher (ID 118, teacher, STEM). This teacher's high betweenness centrality indicated a pivotal role in the network, significantly influencing the dissemination of knowledge by connecting otherwise isolated groups through tweets and mentions. Notably, this teacher was also the highest-ranked actor in outdegree centrality, suggesting a dual role: actively sharing information and bridging diverse subgroups within the network. In other words, the teacher combined high activity levels with a strong bridging function, helping to connect actors who might not otherwise have been linked. Similarly, the instructional coach (ID 5) exhibited both high outdegree and betweenness centrality, indicating a comparable role to the STEM teacher in disseminating and bridging knowledge across the network. The repeated presence of the instructional technology consultant (ID 3) across multiple centrality measures suggests that this actor not only received significant attention from others but also played an active role in connecting otherwise disconnected groups by retweeting and mentioning actors across different parts of the network. Much of the knowledge connected across subgroups related to science, mathematics, technology, and STEM, highlighting active interdisciplinary knowledge circulation during the first year of reform, with engineering, again, notably less prominent in these exchanges.

Eigenvector Centrality

Table 9 presents the breakdown of influence through the lens of eigenvector centrality, which measures how closely an actor is connected to other well-connected actors or accounts within the Twitter network. The findings reveal that the top ten most influential knowledge actors in the district's Twitter network during the first year of the STEM reform were predominantly practice actors, alongside two policy actors. Knowledge actors with high eigenvector centrality were not only well-connected themselves but were also linked to other high-visibility knowledge actors, amplifying their overall influence.

Among the practice actors, three types of knowledge actors were identified: two teachers, two schools, and two specialists (namely, an instructional technology consultant [ID 3] and an instructional coach [ID 5]). The two policy actors identified were a mayor (ID 41) and a public school board association (ID 37). The highest-ranked knowledge actor was a STEM teacher (ID 26, teacher, STEM). This teacher's high eigenvector centrality indicated that they were closely connected to numerous other influential actors, thereby amplifying their visibility and role in the diffusion of knowledge compared to policy actors and research actors.

Table 9. *The extent to which the categories of actors are connected to others who are highly central*

Eigenvector Centrality				
ID	Category of Actor	Specific Actor or Organisation	Subject Matter	Value
26	Practice	Teacher	STEM	0.559
11	Practice	School	Science	0.174
12	Practice	Teacher	Science	0.167
64	Practice	Teacher	Science	0.102
86	Practice	School	Science	0.126
27	Practice	Teacher	Mathematics	0.095
41	Policy	Mayor	Mathematics	0.095
24	Practice	Teacher	Science	0.087
37	Policy	Public school board association	STEM	0.079
18	Practice	School	Mathematics	0.071

This STEM teacher was also the top-ranked actor in indegree centrality, suggesting that they were both highly visible and connected to other prominent actors within the network, making them influential even among other influential actors. Similarly, the two policy actors, the mayor (mathematics and policy) and the public school board association (STEM and policy), were also well-connected to other influential actors, meaning that retweets or mentions from these actors carried greater weight in terms of influence compared to others. Much of the knowledge shared by these well-connected actors centred around science, mathematics, and STEM, indicating that these three subject areas enhanced the prestige and visibility of actors across different groups. By contrast, topics related to technology and engineering were less visible during the first year of the STEM reform.

The Strength of Ties Among Knowledge Actors

This section presents the findings that allowed for the analysis of tie strength within and across subject matter subgroups (e.g., STEM, science, technology, engineering, mathematics) and categories of actors (e.g., practice, research, policy), in order to determine whether ties were weak (infrequent interactions with less familiar others) or strong (frequent interactions with closer others) among subgroups in the school district's Twitter network. Tie strength was assessed using the total number of tweets, retweets, and mentions exchanged among knowledge actors as a proxy for the frequency and closeness of their interactions regarding STEM education. The analysis focused on the extent to which knowledge flowed among actors within subgroups sharing similar profiles (e.g., subject matter focus or actor type) and across different groups. This approach enabled the identification of whether certain subgroups were more likely to share tweets or mentions about STEM education primarily within their own group or more broadly across other groups throughout 2019.

Table 10. *Sum of tie strength across subject matter groups*

	STEM (indegree)	Science	Technology	Engineering	Mathematics
STEM (outdegree)	28	7	0	4	0
Science	18	109	12	1	17
Technology	0	19	0	0	5
Engineering	0	0	0	1	1
Mathematics	9	23	5	0	86

Table 10 presents the sum of tie strength, calculated by the frequency of retweets or mentions among each subject matter subgroup. Among the five subject matter categories, knowledge actors specialising in science most frequently shared tweets or mentions among themselves, recording 109 exchanges over the course of the year. Science actors also engaged with other subgroups, exchanging 18 tweets with STEM actors, 17 with mathematics actors, 12 with technology actors, and 1 with engineering actors. These findings indicate that science actors had the strongest internal ties, facilitating more frequent knowledge exchanges within their own group. Moreover, science was the only subject matter subgroup to exchange tweets with all other

subgroups during the year, underscoring their broader connectivity within the district's Twitter network during 2019.

Knowledge actors in mathematics also demonstrated frequent internal engagement, exchanging 86 tweets or mentions among themselves. They shared 23 tweets with the science subgroup, 9 with STEM, and 5 with technology, but had no exchanges with engineering actors. This suggests that mathematics actors maintained strong internal ties and engaged with three other subgroups, although their connections were not as extensive as those of science actors. STEM knowledge actors shared tweets less frequently among themselves, recording only 28 exchanges over the year. They connected solely with the science and mathematics subgroups and did not engage with technology or engineering actors. Technology actors were significantly less active, sharing no tweets among themselves or with engineering or STEM actors. Instead, they engaged most frequently with science actors, sharing 19 tweets over the year, alongside 5 tweets with mathematics actors, indicating very weak internal and external ties. Engineering actors were the least active subgroup, exchanging just one tweet among themselves and interacting only once with the mathematics subgroup. Their internal and external ties were the weakest across all subject matter categories.

The findings suggest that the strength of ties within the science subgroup facilitated more frequent knowledge exchange about science than in any other subject matter group during the first year of the reform. Science actors demonstrated the strongest internal and cross-subgroup ties, actively sharing knowledge within their own category while also connecting with all other subgroups, although most interactions occurred within the science subgroup itself. Mathematics actors also exhibited strong internal ties and maintained the strongest cross-group relationship with science but did not engage with engineering actors. STEM actors had the third strongest internal ties, shared infrequently with science and engineering actors, and had no interactions with technology or mathematics actors. Technology actors demonstrated no internal ties, engaging most frequently with science, followed by mathematics, while maintaining no exchanges with STEM or engineering. Engineering actors were the least frequent, displaying no internal ties and only a single exchange with a mathematics actor. Overall, science actors played the strongest brokering role within the network, emerging as the most central group in shaping discourse across the school district's Twitter activity.

Table 11. *Sum of tie strength across the three categories of actors*

	Practice (indegree)	Research	Policy
Practice (outdegree)	628	21	171
Research	2	1	3
Policy	19	0	8

Table 11 presents the sum of tie strength, calculated by the frequency of retweets and mentions among each category of actors. Among the three categories, practice actors shared retweets and mentions most frequently among themselves, recording a total of 628 interactions over the course of the first year of the reform. They also exchanged 171 tweets with policy actors and 21 with research actors. These findings indicate that practice actors had the strongest ties, facilitating a higher volume of knowledge exchange within their group. Moreover, practice actors were the only category to share tweets with both other actor groups, positioning them as the most broadly connected category within the district’s Twitter network during the first year of the STEM reform.

In contrast, policy actors shared a significantly lower number of tweets or mentions among themselves, recording only eight interactions throughout the year. They exchanged 19 tweets with practice actors but had no recorded interactions with research actors. Policy actors shared more tweets with practice actors than within their own subgroup and were the only category that did not engage with all other actor groups. This suggests that policy actors maintained weak internal ties and had limited engagement across subcategories, resulting in minimal knowledge exchange within the network. Research actors were the least active group overall. They shared only one tweet among themselves, two with practice actors, and three with policy actors, amounting to a total of six tweets for the year. Like policy actors, research actors engaged more with other subcategories than within their own group; however, their overall level of interaction remained extremely limited. These findings indicate that research actors maintained very weak internal and external ties, contributing minimally to the knowledge exchange within the district’s Twitter network.

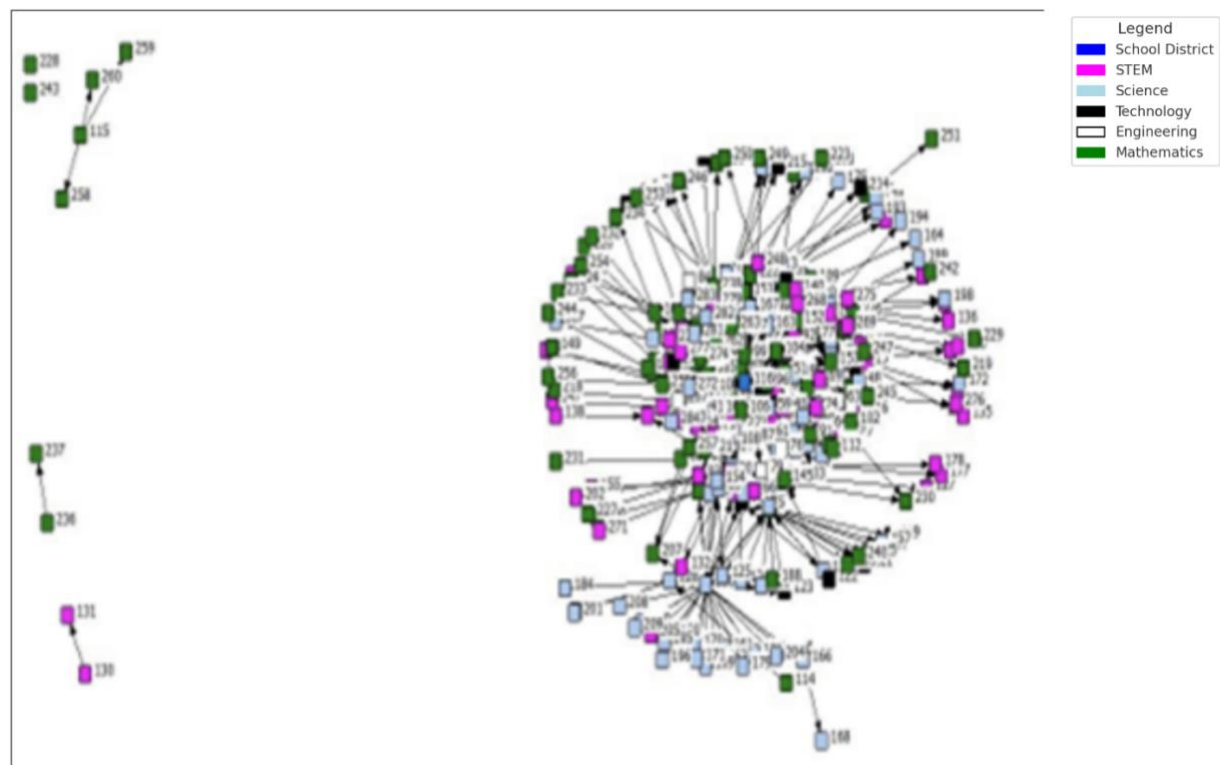
These differences in tie strength among the actor categories suggest varied levels of engagement in knowledge brokering related to the STEM reform. Practice actors demonstrated

the strongest internal and cross-subcategory interactions, actively sharing knowledge within their group and establishing links with both policy and research actors. This positioned them as key knowledge brokers within the network. In contrast, policy actors exhibited weak internal ties and limited external engagement, interacting most frequently with practice actors. Research actors were the least connected overall, displaying minimal interaction either within their group or with others. Overall, practice actors emerged as the strongest brokers of knowledge, highlighting their central position and influence in shaping STEM reform discourse within the district's Twitter network.

The Twitter Network Structure and its Structural Holes in Knowledge Diffusion

This section presents both the structural arrangements and the configuration of relationships within the district's Twitter network concerning STEM, comparing them across the three categories of actors and by subject matter during 2019. The structural arrangements illustrate the broader patterns of interactions among knowledge actors that emerged from these connections. Specific configurations are highlighted through sociograms, enabling visualisation of Twitter networks and distinctions by subject matter and actor category.

Figure 1. *The ego-network including all the knowledge actors and subject matter disciplines*



This graph illustrates the structural arrangements among subgroups of knowledge actors and the school district (ID 116, represented in blue) within the Twitter network in relation to STEM reform over the course of 2019. At the centre of the network is a dense cluster of interconnected knowledge actors, indicating that most were either directly or indirectly linked through retweets, mentions, and their interactions with the school district (the ego).

The broader interaction patterns revealed the presence of several isolated knowledge actors - specifically IDs 130, 131, 228, 243, 236, 237, 258, 115, 260, and 259 - whose lack of connection to the core network created structural holes between themselves and the school district. These isolated actors were all practice actors operating across three subject areas: science, mathematics, and technology. The pattern of interaction indicates that while the school district mentioned or retweeted these actors, they did not reciprocate by mentioning or retweeting the district's content. Consequently, the district engaged with the knowledge they shared only indirectly, via mentions or retweets made by other actors within the network. This explains why these actors are included in the network but appear on its periphery, disconnected from the core.

Among the isolated actors, three distinct clusters were identified: (1) IDs 131 and 130, both associated with STEM; (2) IDs 237 and 236, both engaged in mathematics; and (3) IDs 115, 258, 260, and 259, also mathematics-related, who were connected to one another. These clusters consisted of knowledge actors exchanging information primarily within the same subject area. Additionally, two actors - a mathematics practice actor (ID 251) and a science research actor (ID 168) - were situated on the periphery of the network core. Their tweets were mentioned by other knowledge actors and subsequently retweeted by the school district, highlighting their indirect influence within the network structure.

The Role of Brokers and Structural Holes in Knowledge Diffusion

The knowledge actors located on the lower left-hand side of the graph, specifically the cluster comprising IDs 184, 201, 208, and 209, were connected to the core of the network through a single actor, ID 128 (science, practice). All actors within this cluster were science-based practice actors who relied entirely on ID 128 to link their knowledge to the network core and to the school district. While ID 128 functioned as a broker, the knowledge being relayed was likely redundant, as it originated from actors within the same subject matter (science). This limited the potential for the dissemination of diverse or novel knowledge from this section of the network.

ID 128, a science practice actor, played a clear brokering role by linking a weakly connected cluster of actors - including IDs 184, 196, 201, 205, 208, and 209 - to the network's core. Through this connection, knowledge was primarily facilitated among science actors, with some bridging to a mathematics actor and a STEM actor. Most actors within this cluster were practice actors, and the knowledge exchanged was predominantly related to science. As a result, much of the information shared was likely repetitive, circulated among actors with similar roles and disciplinary backgrounds. Although the STEM and mathematics actors within this cluster may have held distinct or novel knowledge, their limited direct access to the broader network and the school district constrained their influence and ability to disseminate knowledge, as they relied entirely on ID 128 to broker their contributions.

Discussion

This thesis sought to contribute to the growing body of literature on the role of social media, particularly Twitter, and the diverse groups of actors within a school district's Twitter network during the first year of a STEM reform initiative. It investigated how the most influential knowledge actors shaped the dissemination of STEM-related knowledge within the district's Twitter network, employing various centrality measures to capture the multiple ways in which these actors exerted influence. Furthermore, it examined the variation in the strength of ties within and between subgroups of knowledge actors, recognising that strong ties are more likely to facilitate mutual influence on knowledge acquisition. The thesis also analysed the presence of structural holes within the district's Twitter network throughout the first year that the reform was announced.

Recent studies have begun to examine the role of social media, particularly Twitter, in shaping educational policy and political discourse (Daly et al., 2019; Supovitz et al., 2015). These studies have aimed to analyse, visualise, and interpret how social media functions as a platform through which diverse groups, including politicians, journalists, advocacy organisations, professionals, and the general public, contribute to the formation of public discourse, advocacy efforts, and influence. The findings demonstrate how a wide range of actors disseminate information, opinions, and misinformation, thereby influencing public perceptions (Daly et al., 2019; Supovitz et al., 2015). In doing so, those previous studies highlight how the rapid circulation of tweets and retweets can amplify particular narratives, subsequently shaping how both the public and policymakers perceive educational issues and reforms.

The findings from the current study highlight the varying degrees of engagement and activity among categories of knowledge actors within one school district's Twitter network during the first year of a reform in STEM education. As knowledge actors, practitioners were far more active than those involved in policy or research. Previous research has highlighted that practitioners engage actively in peer-driven, accessible professional learning and real-time dialogue, reflecting educators' interest in networks beyond formal policy or research channels. Research on online professional learning networks (PLNs) shows that educators increasingly turn to digital spaces that offer "anytime, anywhere" collaboration with peers, reducing traditional temporal and spatial constraints (Trust et al., 2016). Similarly, educators describe platforms such as Twitter as "efficient, accessible, and interactive," allowing them to connect

with practitioners beyond their own schools and districts (Carpenter & Krutka, 2015). On Twitter, teachers and other school-based staff exchanged examples, resources, and interpretations of reform messages, positioning themselves as primary carriers of implementation knowledge (Carpenter & Krutka, 2015; Trust et al., 2016). The prominence of practitioners as knowledge actors suggests that capacity building during reforms can arise organically from the ground up. When policy leaders support, rather than monitor, these exchanges, they can amplify the diffusion of implementation knowledge across networks of educators (Trust et al., 2016).

This distribution of engagement underscores how the categories of knowledge actors occupy distinct positions in an online policy ecosystem. Practice actors were highly visible and interconnected. This suggests they were leveraging Twitter as an extension of their professional learning communities, a pattern also reported in previous studies (Carpenter & Krutka, 2015; Trust et al., 2016). Policy actors, though formally responsible for shaping reform, appeared less embedded in day-to-day online interactions engaging primarily through limited exchanges. This may indicate they were engaging in symbolic rather than sustained participation, an observation noted by previous researchers (Daly et al., 2019; Oliver, 2021). Research actors were least active, mirroring long-standing challenges in translating academic evidence into local decision-making spaces (Farley-Ripple et al., 2018; Holmlund et al., 2018). Together, these patterns reveal an online network in which practice appears to lead the conversation, policy maintains intermittent visibility, and research remains largely peripheral, a configuration that both reflects and reproduces the traditional gaps between these types of actors (Cooper, 2014; Honig, 2004; Tseng, 2012).

Given the presence of practice-based actors in brokering knowledge, the potential implications of the current study's findings for policy centre on recognising and engaging with these practitioner networks. By cultivating awareness of who holds influence within these networks and how policy-relevant knowledge circulates, leaders can better anticipate how reforms are received and re-narrated in practice (Weber & Yanovitzky, 2021). Encouraging teacher-led knowledge brokering, through formal recognition, structured collaboration time, or integration of practitioner insights into communication strategies, can strengthen alignment between policy intent and local implementation (Rodway et al., 2021; Daly et al., 2019). In this way, policy engagement becomes less about top-down dissemination and more about sustaining a dialogue with those who enact reform on the ground. Education systems could formally

acknowledge online practitioner spaces as arenas for policy translation and professional learning. District and ministry leaders might develop frameworks that support teacher-led knowledge brokering, such as providing dedicated time, recognition, or communication templates, to extend reform messages into classrooms. By institutionalising these informal exchanges, policymakers can strengthen coherence between digital discourse and local implementation (Timotheou et al., 2023).

The District Network's Most Influential Knowledge Actors

The findings of this thesis aligned with previous research that employed centrality measures to emphasise the role of influential actors within Twitter networks and to explore the various types of actors who attract attention in relation to specific educational topics (Daly et al., 2018, 2019; Oliver, 2021; Rehm et al., 2019; Schuster & Kolleck, 2021; Supovitz et al., 2015). These studies adopted a whole-network approach to examine a broad range of influential actors across the network, extending beyond educational practitioners. For example, Schuster and Kolleck (2021) sought to identify influential actors within the wider Twitter discourse on digital learning alternatives. Their analysis revealed that private actors were the most influential, shaping communication networks around digital learning and homeschooling during the COVID-19 pandemic in Germany. This whole-network approach enabled a focus on larger datasets and different contexts that were more likely to capture the voices and perspectives of private actors (Daly et al., 2018, 2019; Rehm et al., 2021; Schuster & Kolleck, 2021).

This thesis adopted an ego-network approach, enabling an examination of the role of social media and the different types of knowledge actors within a single school district's Twitter network in the province of Ontario. Each centrality measure was first analysed to identify the actors who played critical roles in disseminating knowledge across the categories of practice, policy, and research, as well as the types of knowledge shared in relation to STEM and its associated subjects (e.g., science, technology, engineering, and mathematics) during the 2019 year. Furthermore, particular attention was given to the diffusion of knowledge; the approach accounted for both the shares and retweets from the most influential accounts, as well as those originating from within the district itself.

Previous studies have demonstrated how actors with high degree centrality are able to disseminate information more widely and rapidly (del Fresno et al., 2016; Supovitz et al., 2015). Del Fresno et al.'s (2016) emphasised that individuals with high indegree centrality exhibit

distinct influence within a social media network. Their findings indicated that individuals with high degree centrality were instrumental in accelerating the diffusion of information, owing to their extensive connectedness and significant role in facilitating communication across the network. The authors regarded centrality measures as indicators of communication activity. Supovitz et al. (2015) further categorised three types of actors with high degree centrality: (1) transmitters, individuals who sent a large number of tweets using the hashtag #commoncore (high outdegree); (2) transceivers, individuals whose tweets were frequently retweeted or mentioned by others (high indegree); and (3) transmitters, a distinct group who exhibited both high outdegree and high indegree, positioning them as the most influential within the network. They outlined how these three types of actors played critical and distinct roles in shaping discourse, influencing opinion, and driving the dynamics of the #commoncore Twitter network. For instance, transmitters broadcasted a high volume of tweets, disseminating information and opinions related to #commoncore.

In this thesis, the ten most influential knowledge actors with high centrality within a single school district's Twitter network were identified. The findings revealed that actors with high indegree centrality were primarily practice-based actors, specifically teachers, schools, and one instructional technology consultant. According to Supovitz et al. (2015), these actors fulfilled a transceiver role, as their tweets attracted the most attention, receiving the highest number of retweets and mentions by others. Consequently, they served as influential conduits for the dissemination of knowledge related to STEM, mathematics, and science, driven largely by those directly engaged in educational practice. The findings also demonstrated that actors with high outdegree centrality included both practice-based actors and one policy actor, namely teachers, specialists (e.g., an instructional technology consultant and an instructional coach), a school, and an educational network. In line with Supovitz et al. (2015), these actors assumed a transmitter role, sending a high volume of tweets and mentions, and actively sharing content generated by others. As such, they functioned as broadcasters of knowledge related to science, mathematics, technology, and STEM, although notably not in the subject area of engineering. Moreover, one transcender (ID 3) was identified among the top ten knowledge actors, an instructional technology consultant, who both sent tweets and was retweeted or mentioned by the district. According to Supovitz et al. (2015), this indicates that the instructional technology consultant, specialising in mathematics, fulfilled a dual role characterised by both high outdegree

and indegree centrality, rendering them the most influential individual within the network. These also aligns with the findings from the study of Daly et al. (2018) that underscored how actors that held significant influence was not solely determined by the follower count but could also be due to their strategic connections and ability to amplify messages effectively social networks.

Previous studies have highlighted how actors with high betweenness centrality play a critical role in bridging and/or brokering knowledge between otherwise disconnected actors (del Fresno et al., 2016; Daly et al., 2019). Within a Twitter network, such actors are positioned to control the flow of knowledge, introduce new ideas, amplify messages, and ensure that information reaches diverse segments of the network (Daly et al., 2018, 2019). For example, del Fresno et al. (2016) demonstrated how actors with high betweenness centrality functioned as gatekeepers, regulating the flow of information by determining who received specific resources, from whom, and in what form.

In this thesis, the ten most influential knowledge actors with high centrality within the district's Twitter network were identified. The findings revealed that actors with high betweenness centrality spanned all three categories, practice, research, and policy, including teachers, schools, an instructional technology consultant, an instructional coach, a blood service organisation (STEM-related), an advocacy organisation (STEM-related), a superintendent (science), and a university. These actors functioned as brokers of STEM, mathematics, science, and technology knowledge, connecting various subgroups and/or the district itself. It was found that four knowledge actors (IDs 2, 138, 7, and 137), specifically, a blood service organisation, an advocacy organisation, a superintendent, and a university, acted as brokers of STEM and science-related knowledge but did not emerge as influential in other centrality measures. These actors were particularly influential in their ability to bridge knowledge and regulate the flow of knowledge within the Twitter network, as their decisions to retweet or mention others significantly shaped the dissemination of knowledge (Borgatti et al., 2013; Schuster & Kolleck, 2021). These findings complement existing research on the role of teachers in knowledge mobilisation and brokering, which emphasises their capacity to connect stakeholders through the exchange of knowledge within networks (Rodway et al., 2021).

Eigenvector centrality assigns higher scores to accounts within a Twitter network by considering not only the number of connections an account has, but also the extent to which those connections are themselves highly influential (Daly et al., 2019; Supovitz et al., 2015).

Thus, an actor with fewer, yet more influential, connections may attain a higher eigenvector centrality score than an actor with numerous but less influential connections. Such actors play a central role within their respective subgroups and possess the capacity to influence the opinions of others across the network (Daly et al., 2019). In the present thesis, the categories of actors who were most well-connected to influential others were found to be primarily practice-based, in addition to a few policy actors. Six of the ten most influential knowledge actors (IDs 26, 11, 12, 86, 27, and 18) were those who frequently tweeted at or mentioned the district but were not themselves retweeted or mentioned by the district. Furthermore, four knowledge actors (IDs 64, 41, 24, and 37) emerged as highly connected within the areas of STEM, science, and mathematics, yet did not exhibit influence in other centrality measures. These included two policy actors, a mayor and a school board association, and two practice-based actors, both science teachers. The eigenvector centrality results thus revealed the hierarchical structure of the Twitter network, indicating which influential knowledge actors occupied central positions both within the network as a whole and within specific subgroups (Supovitz et al., 2015).

Some studies have combined multiple centrality measures to develop a more comprehensive understanding of the multifaceted ways in which individuals or groups influence and shape the flow of information (Daly et al., 2019; Schuster & Kolley, 2021; Supovitz et al., 2015). For example, Schuster and Kolley (2021) demonstrated how small and medium-sized enterprises, exhibiting both high outdegree and high betweenness centrality, engaged actively and positioned themselves strategically within the Twitter discourse on digital learning and homeschooling during the COVID-19 pandemic. These actors frequently directed information towards specific users, such as teachers, in efforts to promote their products and services.

In this thesis, the top ten influential knowledge actors were examined across three centrality measures: indegree, outdegree, and betweenness. The aim was to determine whether any actors appeared across multiple measures and to explore the multifaceted ways in which they exerted influence within the district's Twitter network. The findings revealed that the knowledge actor ranked first in both outdegree and betweenness centrality, a STEM teacher (ID 118), fulfilled a dual role as both transmitter and broker. High values in both measures suggest that this teacher was not only influential in disseminating information but also pivotal in brokering knowledge between groups that might otherwise have remained disconnected. Similarly, a science-focused school (ID 11), which exhibited high indegree and betweenness centrality,

emerged as both a popular source of knowledge and a key actor in connecting various parts of the network. This dual role enhanced the school's capacity to broker knowledge effectively, ensuring that information reached diverse audiences and fostering collaboration across different groups.

Furthermore, an instructional coach (ID 5) and a technology teacher, both displaying high outdegree and betweenness centrality, actively sought to gain attention by sending the most mentions and retweets, while simultaneously bridging otherwise disconnected groups. In other words, these two knowledge actors, with their combined high outdegree and betweenness centrality, played pivotal roles in both disseminating information and connecting diverse subgroups that would not otherwise have been exposed to the same knowledge flows. Notably, the instructional technology consultant (ID 3) was identified as one of the most influential actors across all three centrality measures: indegree, outdegree, and betweenness. This indicates a multi-dimensional influence, positioning the consultant, in line with Supovitz et al. (2015), as a transcender - an actor who both received significant attention, actively shared information, and brokered connections across disparate areas of the network.

Thus, by combining multiple centrality measures, this thesis was able to capture the various ways in which knowledge actors exerted influence within the Twitter network, rather than relying on a single metric of influence (Schuster & Kolleck, 2021). This approach enabled a more nuanced understanding of which actors were best positioned to share knowledge with the school district and to shape discourse around the STEM reform and its potential implementation within the district.

How the Strength of Ties Shapes Knowledge Diffusion Between and Across Subgroups

The strength of ties within a social network plays a crucial role in uncovering patterns of knowledge diffusion both within and across subgroups. Previous studies have emphasised that reciprocal ties, or mutual relationships, significantly enhance trust, thereby supporting the continuation and deepening of these connections (Daly et al., 2019). Such ties are particularly important as they shape the flow of information and resources throughout the network. An understanding of the composition of weak and strong ties offers valuable insights into how information circulates, how influence is exerted, and the extent of cohesion or fragmentation within subgroups (Daly et al., 2019; Oliver, 2021).

In this thesis, the strength of ties within subgroups was examined, based on the subject matter and the category of knowledge actors comprising the district's Twitter network. The findings concerning the strength of ties within distinct subject matter subgroups revealed that knowledge actors within the science, mathematics, and STEM subgroups exhibited the highest frequency of tweet and mention exchanges among themselves. This indicated stronger ties, characterised by more frequent interactions, which were more likely to facilitate the rapid and reliable exchange of information within these subgroups (Daly et al., 2009; Oliver, 2021). It also suggested that knowledge was predominantly shared among actors who possessed similar traits (e.g., beliefs, values, and trust), thereby creating stronger internal cohesion around subject-specific knowledge. In contrast, the technology and engineering subgroups exhibited the weakest ties, with infrequent or only occasional exchanges of tweets and mentions within their respective subgroups. This relatively low frequency of interaction indicated that these actors were less connected internally, potentially limiting the flow of information and reflecting a less cohesive structure in which influence was less strongly exerted through shared traits (Oliver, 2021). Nevertheless, weaker ties of this kind can extend an individual's reach and influence beyond their immediate subgroup, enabling access to and mobilisation of resources from other parts of the wider network.

Subsequently, the strength of ties across subgroups, based on the subject matter composition of the district's Twitter network, was investigated. The findings indicated that knowledge actors within the science and mathematics subgroups exhibited strong ties with actors in other subgroups, apart from engineering, suggesting that they more frequently shared and brokered information across different domains of knowledge within the network. By contrast, the STEM subgroup demonstrated a lower frequency of knowledge exchange with other subgroups and no recorded interactions with the technology and engineering subgroups. This reduced level of interaction may reflect a more fragmented approach to knowledge sharing, thereby making it more challenging to bridge connections across different parts of the network.

STEM-related terms appeared less frequently than expected, including those associated with technology and engineering. This imbalance reflects systemic factors in K-12 education, where engineering and technology are often less emphasised in teacher preparation, curriculum design, and assessment frameworks (English, 2016; Falloon et al., 2020). Teachers frequently report low confidence in delivering engineering design or coding activities, leading to minimal

discussion of these disciplines both offline and in online professional networks. The limited visibility of STEM and engineering tweets likely signals broader capacity gaps rather than disinterest (DeCoito, 2016; Industry Canada, 2007). Moreover, the inconsistent use of the term “STEM” itself may contribute to this pattern. As Holmlund et al. (2018) note, the label is often applied rhetorically to signal alignment with innovation or economic priorities rather than to describe fully integrated practice. Similarly, English (2016) and DeCoito (2016) argue that educators and policymakers frequently invoke “STEM” as shorthand for science and mathematics, with technology and engineering implicitly subsumed or sidelined. This conceptual broadness can obscure disciplinary distinctions, allowing discussions to appear comprehensive while masking uneven emphasis within STEM fields.

The strength of ties within subgroups was assessed based on the category of knowledge actors comprising the district’s Twitter network. The findings indicated that practice actors exhibited the highest frequency of tweet and mention exchanges among themselves. This suggests that stronger ties, fostered through frequent interactions, were more likely to facilitate the rapid and reliable exchange of information within the practice-based subgroup. Policy-based actors demonstrated a moderate strength of ties within their subgroup, indicating that their connections were sufficiently strong to enable clear and effective knowledge diffusion, yet not so strong as to result in redundancy (Supovitz et al., 2018). In contrast, the research-based subgroup exhibited the weakest ties, characterised by infrequent or only occasional exchanges of tweets and mentions. This suggests that while the subgroup may have been positioned to introduce new information from other parts of the network, the limited frequency of interaction constrained the depth and reliability of STEM-related knowledge sharing (Daly et al., 2019).

The strength of ties across subgroups was analysed based on the category of knowledge actors comprising the district’s Twitter network. Practice actors demonstrated a higher frequency of interactions with policy actors compared to research actors. This finding highlights the potential role of practice-based actors in facilitating the transfer of knowledge from practice to policy contexts, positioning them as conduits for the translation of practice into policy. Policy actors exhibited the lowest frequency of interactions both within their own subgroup and with research actors, although their engagement with practice actors was comparatively more frequent. This suggests that, while policy actors were less involved in frequent internal or cross-subgroup exchanges, they nonetheless maintained important connections with practice actors.

Research actors demonstrated the least amount of interaction, both within their own subgroup and with others. This low level of engagement may have indicated a more isolated approach to knowledge dissemination or potential challenges in establishing connections with practice and policy actors. Such isolation may have limited their ability to exert influence on other subgroups; however, it may have also positioned them advantageously by providing access to non-redundant and novel knowledge, which could prove valuable to other actors within the network and the district more broadly.

It was found that, across both the categories of knowledge actors and subject matter, actors were more likely to exchange knowledge within their own subgroup rather than with members of other subgroups. This pattern aligns with what previous studies have defined as "homophily" - the tendency for individuals to associate with others who share similar views, thereby leading to the formation of homogeneous subgroups (Daly et al., 2019). In this thesis, this tendency was evident in the way knowledge actors within subgroups interacted predominantly with those who occupied similar positions or shared common interests in terms of subject matter, rather than engaging with actors from different groups.

Numerous studies have emphasised the importance of strong ties to other actors within a network as critical for influencing educational policy discussions. Rodway et al. (2021) highlighted how stronger ties, fostered through repeated interactions, were essential for more effective knowledge brokering. Similarly, Daly et al. (2019) demonstrated that strong ties enhanced the ability to disseminate knowledge and shape policy discourse more effectively. Barnes (2023) further argued that strong ties could be strategically leveraged for lobbying and influence, facilitating the formation of cohesive groups capable of amplifying particular narratives and, in doing so, potentially polarising public opinion on educational issues. That said, while strong ties offer certain advantages, previous research has also suggested that they may stifle innovation; actors embedded within dense networks of strong ties are more likely to access and circulate similar or redundant information (Granovetter, 1973), which may ultimately limit the diversity of ideas and reduce the capacity to exert broader influence.

The sparsity of the district's Twitter network presents considerable opportunities for various actors to leverage weak ties to enhance reachability, extending influence across and between subgroups, diversify their connections, and potentially accelerate the dissemination of knowledge to disparate parts of the network (Granovetter, 1973). Weak ties offer a means of

bridging different subgroups, facilitating (or constraining) access to novel knowledge that may not be readily available within an actor's immediate network of strong ties (Burt, 1992; Granovetter, 1973). By serving as conduits between distinct subgroups, actors can exert control over the flow of knowledge and introduce new ideas that may play a critical role in shaping online policy discussions and, ultimately, influencing education reform.

While previous studies have largely focused on strong ties, the analysis of the composition of weak, mid-strength, and strong ties in this thesis allows for the provision of valuable insights into the dynamics within and across different types of subgroups in the network. Categorising the strength of ties enabled the identification of fragmented patterns in knowledge diffusion, highlighting which subject areas and categories of actors engaged in frequent interaction and which appeared to be less active in sharing, sending, or receiving tweets and mentions. This approach also allowed for the identification of subgroups with the potential to perform a bridging function between otherwise disconnected parts of the network - an especially important consideration in policy and reform discussions. For instance, establishing bridges between the engineering and technology subgroups and other areas could enhance the diffusion of new knowledge, facilitating the exchange of novel information across the network. In other words, these findings could inform the design of strategies for more effective policy influence by targeting weak and mid-strength ties within the district's Twitter network to strengthen knowledge sharing and connection around STEM education reform efforts across different subject matter subgroups and categories of actors.

The strength of ties presented both advantages and limitations. While a network characterised by strong ties offers certain benefits, it is also more likely that the knowledge circulating within such networks is redundant, meaning that actors are repeatedly exposed to similar types of information (Granovetter, 1973). Conversely, networks composed of weak ties provide opportunities for accessing broader perspectives and fostering innovation, helping to overcome homogeneity and facilitating the introduction of new knowledge. Such dynamics can be particularly advantageous in enhancing collaboration, promoting innovation, and building broader support for reform initiatives.

Structural Holes

Previous studies have demonstrated the role of structural holes in facilitating knowledge diffusion within Twitter networks (Daly et al., 2019; Supovitz et al., 2015). The presence of

structural holes offers valuable insights into how certain messages or information can spread widely and rapidly across diverse subgroups, as brokers play a critical role in connecting otherwise disconnected groups and ensuring the flow of information throughout the network. In this thesis, the findings highlighted the role of practice-base actors, specifically teachers and school-facing individuals, as key brokers within the district's Twitter network. These knowledge actors not only bridged structural holes but also frequently shared information across different subgroups. The centrality of practice actors in brokering knowledge suggests that they exercised considerable influence over the dissemination of STEM-related and associated subject matter within the network over the course of the reform year. Consequently, they played a pivotal role in shaping the flow and diffusion of knowledge within the district's Twitter network during this period.

The school district's network comprised both well-connected actors and isolates. The gaps between the network's core and its isolates presented both opportunities and challenges for knowledge dissemination. Actors occupying brokerage positions played a critical role in bridging these structural holes and connecting peripheral actors to the network's core. These brokers served as intermediaries who could either facilitate or constrain the flow of knowledge, thereby influencing whether information external to the core was transmitted or withheld. Positioned strategically, brokers had the capacity to control both the timing and content of the information shared, placing them in a powerful position within the network. By selecting which knowledge was disseminated to the core, brokers influenced which ideas gained traction and how these ideas were incorporated into broader discussions surrounding STEM reform.

The sociogram revealed that the network was unevenly connected, highlighting areas where the flow of knowledge did not extend efficiently beyond the core. This suggested that peripheral actors were largely dependent on a small number of brokers to facilitate their integration into the network. While these structural gaps provided opportunities for brokers to increase their influence, they also posed significant challenges for ensuring that all actors, particularly those located at the periphery, could actively contribute to and benefit from shared knowledge within the district's Twitter network. Should a broker choose to constrain the flow of knowledge, it would have widespread effects, particularly on actors not well connected to the core, with potential implications for the district's overall access to diverse sources of knowledge.

The findings of this thesis provided insights into how a small number of actors within the network played a pivotal role in connecting different parts of the school district's Twitter network, by leveraging their strategic positioning as identified through measures of betweenness centrality. School-facing practice actors, predominantly teachers and schools, emerged as the most effective brokers within the network, facilitating the exchange of knowledge by linking otherwise disconnected parts of the network (Rodway et al., 2021). Occupying structural holes is particularly critical for actors seeking to gain influence within policy networks. These actors do not depend on formal titles or hierarchical positions; rather, they employ strategic tactics to strengthen their network positioning and relationships, enabling them to act as gatekeepers who control and shape the flow of information between otherwise isolated actors (Borgatti et al., 2013; Burt, 1992; Oliver, 2021; Rehm et al., 2019).

Bridging roles are also essential for maintaining communication during dynamic periods of change (Schuster & Kolleck, 2021). The few actors within the school district's network who exhibited high betweenness centrality held a distinct form of influence, belonging to a small subset capable of either facilitating or constraining knowledge exchange. Their control over what knowledge circulated, and who it reached, positioned them to exert considerable influence over the district's discourse around STEM reform.

The structural holes between the school district and the isolates presented opportunities for the isolates, brokers, and the district itself. The district had the potential to access novel knowledge from these policy- and practice-based isolates, placing it in an advantageous position, as actors located outside the district's core are more likely to possess information and knowledge not yet embedded within the core network (Borgatti et al., 2013; Crossley et al., 2015). While previous research (Oliver, 2021; Rehm et al., 2021; Rodway et al., 2021; Schuster & Kolleck, 2021) has offered insights on a larger scale, often focusing on national-level policy discussions, the present findings highlight similar dynamics at the local level. Specifically, the ability to bridge structural holes enabled network actors to wield influence within the social network, including in online spaces.

Limitations and Future Research

While this thesis presents valuable insights into the potential for Twitter to be used as a platform for influence around STEM education reform, it also had its limitations.

First, this analysis was based solely on Twitter-derived data. Although other studies (e.g., Schuster and Kolleck, 2021) have adopted a similar approach, future research could benefit from incorporating additional methods to better contextualise the content of tweets shared between the district and other actors in the network, as well as to explore the behavioural aspects and motivations of these actors. A deeper understanding of the actors' intentions across different subject matter areas and knowledge categories would have provided further insight into their motivations and the types of knowledge they sought to disseminate. This thesis prioritised a quantitative approach and did not complement the Twitter data with additional methods (e.g., text analysis, interviews) that could have helped contextualise the scraped tweets. Furthermore, this research differed from much of the existing literature in that it employed an ego-network approach, focusing on the school district as the network's ego, rather than a whole-network analysis. We believe that the approach, and the data collected and analysed, were appropriate for a master's-level research project, particularly given that the use of social network analysis (SNA) to examine social-media-derived data remains a novel methodology within educational policy research. Even today, few studies in the field of education make use of social-media-derived data, highlighting the continued innovation of this approach to data collection and analysis.

Second, to better understand the impact of the Ministry of Education's reform announcement, a longitudinal approach could be beneficial to see the effects of the announcement on the network overtime. This cannot be understood as easily when a static approach to web scraping is taken. Previous studies (e.g., Rodway et al., 2021) analysed how a network changed overtime and the implications of this on policy. Understanding how the school district's Twitter network evolved overtime could have also provided additional insight into actors' motivations.

Finally, the dataset was limited to five specific search terms (STEM, science, technology, engineering, mathematics), which defined the parameters of this thesis. As a result, it is possible that other STEM-related actors and tweets were missed during the data collection process. Although this approach was deemed appropriate for a master's-level thesis, employing a more robust web-scraping strategy could yield additional data, offering a more comprehensive understanding of who is central to these discussions and how STEM knowledge is interpreted and shared across a Twitter network.

It is also important to note that the rebranding of Twitter to “X” signifies a big shift in the platform’s functionality, user interaction, and data availability. As a result, future research will likely require a different approach to analysis, which would take shape differently than how it was approached for this thesis. Moreover, since Twitter’s rebrand in 2022, there has been a marked decline in both user numbers and activity (Hern, 2024), underscoring the growing difficulty of conducting research of this nature due to the platform’s diminishing user engagement.

Nevertheless, the approach that was taken makes an original contribution to a limited body of research, especially in Canada, around the impact of an online Twittersphere on STEM education reform. The combination of a computer science techniques and social network analysis to better understand the network of a medium-sized school district the year of a reform announcement provided a novel approach to understanding influence in the field of educational policy as we experience the continued fusion between online and offline spaces.

Conclusion

This thesis demonstrates the potential of social media platforms, specifically Twitter, as tools for disseminating knowledge within policy reform and practice environments. By examining a mid-sized Ontario school district's Twitter network in the year of a major STEM reform announcement, this research offers insights into the role of the most influential knowledge actors using centrality measures, assessing how tie strength varied within and across actor subgroups, and analysing how knowledge brokers bridged subgroups across structural holes in the network, and how these various influential actors shaped the diffusion of STEM-related knowledge. Drawing on social network analysis, this thesis examined the roles and interactions of practice, policy, and research actors within the network.

The study identified several influential knowledge actors within the school district's Twitter network, connecting otherwise disconnected actors. These actors - teachers and other school-facing specialists - served as brokers who facilitated the flow and exchange of STEM-related knowledge in the period of reform addressing STEM education. Their network positioning and activity helps illustrate that policy learning often occurs laterally, through educators' interpretation and adaptation rather than through official directives. Recognising and resourcing these brokers can strengthen policy implementation. Policymakers could formally include teachers in communication design or provide small-scale grants, for example, for knowledge sharing to ensure that reform messages are co-constructed with practitioners (DeCoito, 2016; Holmlund et al., 2018; Industry Canada, 2007).

Practice-based knowledge actors, especially teachers and others in school-facing roles, emerged as the most central and connected knowledge brokers in the district's Twitter network. They not only shared the most content but also bridged different subgroups and were the only category to engage across all knowledge actor types, including those focused on policy and research. This aligned with prior literature suggesting that brokerage is often enacted by those in informal roles who are strategically positioned to influence knowledge flows (Oliver, 2021; Rodway et al., 2021; Weber & Yanovitzky, 2021). Their engagement centred around key subject areas, particularly mathematics and science, highlighting the uneven attention different STEM subject matter disciplines received during the first year of the reform.

The thesis also highlighted the dual roles of strong and weak ties in shaping knowledge diffusion. While strong intra-group ties, especially among practice actors, fostered trust and

cohesion, they also risked redundancy in knowledge circulation. In contrast, weak ties and structural holes provided opportunities for novel information to flow across subgroups. Brokers who bridged these gaps played a pivotal role in extending influence beyond one's own subgroup and throughout the network.

Implications for Educational Policymakers and Practitioners

This thesis contributes to existing research that highlights how online platforms, such as social Twitter, are reshaping the dynamics of policy discourse. In line with work by Daly et al. (2019), Oliver (2021), and Rodway et al. (2021), the findings suggest that actors positioned centrally in a network, particularly those acting as bridges across subgroups, can play a role in shaping how information circulates, even in the absence of formal authority. In this case, practice-based actors, including classroom teachers and other school-facing actors, frequently occupied these bridging positions and emerged as central figures in the flow of STEM-related knowledge during the first year of reform. These results also echo Schuster & Kolleck's (2021) use of centrality measures to demonstrate how individuals without formal policy roles can exert influence within education policy networks. Similar to their findings, this thesis shows that the visibility and structural positioning of actors within the network, rather than their formal title, can correlate strongly with their capacity to broker and diffuse knowledge. Centrality, in this context, can be understood as a useful heuristic for identifying influential voices in an online policy landscape. The thesis also aligns with research on knowledge brokering that identifies teachers as capable of occupying central and influential roles under the right relational and organisational conditions (Rodway et al., 2021). Here, practitioners were not simply passive recipients of information but were active in sharing knowledge across diverse groups. The implications are not to encourage additional professional responsibilities or online engagement for educators, but rather to recognise and better understand the influence practitioners may already exert within online spaces, particularly in the early stages of reform when narratives and meanings are still forming.

Rather than recommending that policymakers actively engage on social media platforms, the findings support broader calls in the literature for developing network awareness (Weber & Yanovitzky, 2021), an understanding of who holds influence in online networks and how policy-relevant knowledge moves across them. Monitoring such interactions may offer policymakers a clearer picture of how reform messages are received, interpreted, or reshaped. This is especially

relevant in light of the present thesis's findings, which show that policy and research actors were less connected across the school district's network, potentially limiting their visibility and reach. For practice, these findings suggest that districts can treat online networks as extensions of professional learning spaces. Administrators might allocate structured time or recognition for teachers who disseminate resources and model implementation in open networks. For research, these results call for more systematic collaboration between scholars and practitioners, using social-media environments not merely as outreach tools but as arenas for participatory inquiry and rapid knowledge exchange (Carpenter & Krutka, 2015; Trust et al., 2016; Veletsianos, 2017).

These findings must be understood within the limitations of the thesis. The analysis focused on interactional structure, not the content or intent behind shared messages. As such, conclusions about influence relate to visibility and positioning in the network, rather than claims about the persuasiveness or legitimacy of an actor's contributions. Nevertheless, the prominence of practice-based actors in key positions suggests that educators can, and do, shape the online discourse surrounding education policy, sometimes more visibly than formally designated policy actors. These observations may inform how future reforms, even at the local level, are communicated and how online networks are studied and interpreted in educational policy research.

Implications for Future Research

This thesis reinforces the relevance and adaptability of social network analysis as a methodological approach to understanding policy processes in online spaces. While the current research provides a snapshot of influence during the early stages of Ontario's 2019 STEM reform, the static nature of the data limits the ability to capture how network structures or actor roles shift over time. Future research could expand on this work by using a longitudinal study approach to explore these changes, particularly to understand whether certain actors maintain their influence, whether new brokers emerge, or how reform discourse evolves as policy implementation progresses. This would build on the current findings and offer a more dynamic view of influence and network engagement from the network's actors. Moreover, given that this thesis focused on patterns of interaction, rather than content, future work could also incorporate qualitative methods, such as content analysis or interviews, to examine what kinds of knowledge are being shared and how actors understand their roles in the network. These methods would

provide a more robust view of how meaning is constructed and circulated alongside network positioning.

As Twitter/X continues to change in terms of functionality, ownership, and user behaviour, future research might also consider how influence operates across different platforms. Established alternatives (e.g., Facebook, LinkedIn) may support more formal, professional exchanges; while emerging or niche platforms could foster different forms of participation or visibility. Comparing across platforms could help identify whether brokerage patterns observed in this thesis are platform-specific or more widely applicable. Such comparisons could also reveal whether the type of platform affects who becomes visible, how networks form, and what kinds of knowledge are prioritised. Since this study analysed activity within the 2019 Twitter network and provided a snapshot of district engagement during that period, it is important to note that online platform selection and uptake may have shifted. Since 2019, educator communication has diversified across platforms, reflecting a broader fragmentation of professional learning networks as educators seek new digital spaces for connection (Koutropoulos et al., 2024). Despite these shifts, the core insight endures - effective reform depends on maintaining open, multidirectional knowledge flow among teachers, researchers, and policymakers. Districts should design adaptable communication ecosystems that evolve with technology but continue to prioritise practitioner voice, cross-sector collaboration, and transparent knowledge sharing (Trust et al., 2016; Veletsianos, 2020).

Finally, expanding this work to include different educational contexts, such as larger school districts or international settings, would support the testing of these findings in diverse policy environments. This could help clarify the extent to which online network dynamics in education are context-dependent and contribute further to the field's understanding of how policy processes unfold in the digital age.

References

- Aichner, T., Grünfelder, M., Maurer, O., & Jegeni, D. (2021). Twenty-five years of social media: A review of social media applications and definitions from 1994 to 2019. *Cyberpsychology, Behavior and Social Networking*, 24(4), 215–222. <https://doi.org/10.1089/cyber.2020.0134>
- Barnes, N., Watson, S., & MacRae, S. (2023). The moral positioning of education policy publics: How social media is used to wedge an issue. *Critical Studies in Education*, 64(4), 337–354. <https://doi.org/10.1080/17508487.2022.2153372>
- Bastian, M., Heymann, S., & Jacomy, M. (2009, March 19). Gephi: An open source software for exploring and manipulating networks. <https://doi.org/10.13140/2.1.1341.1520>
- Bercovici, J. (2010, December 9). Who coined “social media”? Web pioneers compete for credit. *Forbes*. <https://www.forbes.com/sites/jeffbercovici/2010/12/09/who-coined-social-media-web-pioneers-compete-for-credit/>
- Borgatti, S. P., Everett, M. G., & Freeman, L. C. (2002). *Ucinet 6 for Windows: Software for Social Network Analysis*. Harvard, MA: Analytic Technologies.
- Borgatti, S. P., & Cross, R. (2003). A relational view of information seeking and learning in social networks. *Management Science*.
- Borgatti, S. P., Everett, M. G., & Johnson, J. C. (2013). *Analyzing Social Networks*. London: Sage.
- Borgatti, S. P., & Halgin, D. S. (2011). On network theory. *Organization Science*, 22(5), 1168–1181. <https://doi.org/10.1287/orsc.1100.0641>
- Brass, D. J. (2022). New developments in social network analysis. *Annual Review of Organizational Psychology and Organizational Behavior*, 9(Volume 9, 2022), 225–246. <https://doi.org/10.1146/annurev-orgpsych-012420-090628>
- Burt, R. S. (1992). *Structural Holes: The Social Structure of Competition*. Harvard University Press. <https://www.jstor.org/stable/j.ctv1kz4h78>
- Burt, R. S. (2000). The network structure of social capital. *Research in Organizational Behavior*, 22, 345–423. [https://doi.org/10.1016/S0191-3085\(00\)22009-1](https://doi.org/10.1016/S0191-3085(00)22009-1)
- Burt, R. S. (2004). Structural holes and good ideas. *American Journal of Sociology*, 110(2), 349–399. <https://doi.org/10.1086/421787>

- Carpenter, J. P., & Krutka, D. G. (2015). *Engagement through microblogging: Educator professional development via Twitter*. *Professional Development in Education*, 41(4), 707–728. <https://doi.org/10.1080/19415257.2014.939294>
- Carpenter, J. P., & Krutka, D. G. (2014). How and why educators use Twitter: A survey of the field. *Journal of Research on Technology in Education*, 46(4), 414–434. <https://doi.org/10.1080/15391523.2014.925701>
- Coleman, J., Katz, E., & Menzel, H. (1957). The diffusion of an innovation among physicians. *Sociometry*, 20(4), 253–270. <https://doi.org/10.2307/2785979>
- Cooper, A. (2013). Research mediation in education: A typology of research brokering organizations that exist across Canada. *Alberta Journal of Educational Research*, 59(2), 181–207.
- Cooper, A. (2014). *Knowledge brokers: Facilitating the connection between research and practice in education*. *Education Policy Analysis Archives*, 22(122). <https://doi.org/10.14507/epaa.v22.355>
- Crossley, N., Bellotti, E., Edwards, G., Everett, M. G., Koskinen, J., & Tranmer, M. (2015). *Social Network Analysis for Ego-Nets*. SAGE Publications Ltd. <https://doi.org/10.4135/9781473911871>
- Daly, A. J., Fresno, M. del, & Supovitz, J. A. (2018). The impact of the “social” in social media space: A systems perspective on educational policy and leadership. In *Leading Holistically*. Routledge.
- Daly, A. J., Moolenaar, N. M., Bolivar, J. M., & Burke, P. (2009). Relationships in reform: The role of teachers’ social networks. *Journal of Educational Administration*, 48(3), 359–391. <https://doi.org/10.1108/09578231011041062>
- Daly, A. J., Supovitz, J., & Fresno, M. D. (2019). The social side of educational policy: How social media is changing the politics of education. *Teachers College Record*, 121(14), 1–26. <https://doi.org/10.1177/016146811912101402>
- Datnow, A., & Park, V. (2010). Success for All: Using tools to transport research-based practices to the classroom. In *Research and Practice in Education: Building Alliances, Bridging the Divide* (p. 256). Rowman & Littlefield Publishers.

- DeCoito, I. (2016). STEM education in Canada: A knowledge synthesis. *Canadian Journal of Science, Mathematics and Technology Education*, 16(2), 114–128.
<https://doi.org/10.1080/14926156.2016.1166297>
- del Fresno García, M., Daly, A. J., & Segado Sánchez-Cabezudo, S. (2016). Identifying the new influences in the Internet era: Social media and social network analysis. *Identificando a Los Nuevos Influyentes En Tiempos de Internet: Medios Sociales y Análisis de Redes Sociales.*, 153, 23–40. <https://doi.org/10.5477/cis/reis.153.23>
- Demandsage. (2024, May 15). *Twitter (X) statistics and facts for 2024: Usage, revenue & more.*
<https://www.demandsage.com/twitter-statistics/>
- Dorsey, J. (2012, November 15). Twitter takes the pulse of the planet. It's the intersection of every media & medium. Twitter.
- English, L. D. (2016). STEM education K–12: Perspectives on integration. *International Journal of STEM Education*, 3(3). <https://doi.org/10.1186/s40594-016-0036-1>
- Falloon, G., Hatzigianni, M., Bower, M., Forbes, A., & Stevenson, M. (2020). Understanding K–12 STEM education: A framework for developing STEM literacy. *Journal of Science Education and Technology*, 29(3), 369–385. <https://doi.org/10.1007/s10956-020-09823-x>
- Farley-Ripple, E. N., May, H., Karpyn, A., Tilley, K., & McDonough, K. (2018). *Rethinking connections between research and practice in education: A conceptual framework.* *Educational Researcher*, 47(4), 235–245. <https://doi.org/10.3102/0013189X18761042>
- Finnigan, K. S., Daly, A. J., & Che, J. (2013). Systemwide reform in districts under pressure: The role of social networks in defining, acquiring, using, and diffusing research evidence. *Journal of Educational Administration*, 51(4), 476–497.
<https://doi.org/10.1108/09578231311325668>
- Golbeck, J. (2013). Analyzing the social web. <https://doi.org/10.1016/C2012-0-00171-8>
- Granovetter, M. S. (1973). The strength of weak ties. *American Journal of Sociology*, 78(6), 1360–1380.
- Government of Canada. (2007). *Mobilizing science and technology to Canada's advantage.* Industry Canada.
- Hansen, D., Shneiderman, B., & Smith, M. (2011). Analyzing social media networks with nodexl: Insights from a connected world. <https://doi.org/10.1016/C2009-0-64028-9>

- Hern, A. (2024, March 26). Twitter usage in US 'fallen by a fifth' since Elon Musk's takeover. The Guardian. <https://www.theguardian.com/technology/2024/mar/26/twitter-usage-in-us-fallen-by-a-fifth-since-elon-musks-takeover>
- Holmlund, T. D., Lesseig, K., & Slavitt, D. (2018). Making sense of “STEM education” in K–12 contexts. *International Journal of STEM Education*, 5(32). <https://doi.org/10.1186/s40594-018-0127-2>
- Honig, M. I. (2004). The new middle management: Intermediary organizations in education policy implementation. *Educational Evaluation and Policy Analysis*, 26(1), 65–87. <https://doi.org/10.3102/01623737026001065>
- Kolleck, N. (2016). Uncovering influence through social network analysis: The role of schools in education for sustainable development. *Journal of Education Policy*, 31(3), 308–329. <https://doi.org/10.1080/02680939.2015.1119315>
- Koutropoulos, A., Stewart, B., Singh, L., Sinfield, S., Burns, T., Abegglen, S., Hamon, K., Honeychurch, S., & Bozkurt, A. (2024). *Lines of flight: The digital fragmenting of educational networks*. *Journal of Interactive Media in Education*, 2024(1), 1–14. <https://doi.org/10.5334/jime.827>
- Liou, Y.-H., & Daly, A. J. (2020). Obstacles and opportunities for networked practice: A social network analysis of an inter-organizational STEM ecosystem. *Journal of Educational Administration*, 59(1), 94–115. <https://doi.org/10.1108/JEA-02-2020-0041>
- Liou, Y.-H., Daly, A. J., Brown, C., & Fresno, M. del. (2015). Foregrounding the role of relationships in reform. *The International Journal of Educational Management*, 29(7), 819–837. <http://dx.doi.org.proxy.bib.uottawa.ca/10.1108/IJEM-05-2015-0063>
- Malik, A., Heyman-Schrum, C., & Johri, A. (2019). Use of Twitter across educational settings: A review of the literature. *International Journal of Educational Technology in Higher Education*, 16(1), 36. <https://doi.org/10.1186/s41239-019-0166-x>
- Mitchell, R. (2018). *Web Scraping with Python: Collecting More Data from the Modern Web*. O'Reilly Media, Inc.
- Moukarzel, S., Rehm, M., Fresno, M. del, & Daly, A. J. (2020). Diffusing science through social networks: The case of breastfeeding communication on Twitter. *PLOS ONE*, 15(8), e0237471. <https://doi.org/10.1371/journal.pone.0237471>

- Nahapiet, J., & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage. *Academy of Management Review*, 23(2), 242–266.
<https://doi.org/10.5465/amr.1998.533225>
- Oliver, K. (2021). “Being important” or “knowing the important”: Who is best placed to influence policy? In M. S. Weber & I. Yanovitzky (Eds.), *Networks, Knowledge Brokers, and the Public Policymaking Process* (pp. 49–69). Springer International Publishing.
https://doi.org/10.1007/978-3-030-78755-4_3
- Ontario. (2020). The Ontario curriculum, grades 1-8. Mathematics. Toronto: Ontario, Ministry of Education).
- Ontario Government. (2019, March 15). Education that works for you – modernizing learning. [Press release]. Retrieved from <https://news.ontario.ca/en/backgrounder/51527/education-that-works-for-you>
- Ontario Government. (2019, August 28). First year investment of Ontario's four-year mathematics strategy announced. [Press release]. Retrieved from <https://news.ontario.ca/en/release/53479/first-year-investment-of-ontarios-four-year-mathematics-strategy-announced>
- Ontario Government. (2023, April 16). Ontario launches plan to boost mathematics, writing and reading skills. [Press release]. Retrieved from <https://news.ontario.ca/en/release/1002937/ontario-launches-plan-to-boost-mathematics-writing-and-reading-skills>
- Pew Research Center. (2022, June 16). *Politics on Twitter: One-third of tweets from U.S. adults are political*. <https://www.pewresearch.org/politics/2022/06/16/politics-on-twitter-one-third-of-tweets-from-u-s-adults-are-political/>
- Python Software Foundation. (2021). Python (Version 3.9) [Programming language]. <https://www.python.org>
- Rainie, L., & Wellman, B. (2012). *Networked: The new social operating system*. The MIT Press.
<https://doi.org/10.7551/mitpress/8358.001.0001>
- Rehm, M., Cornelissen, F., Notten, A., Daly, A., & Supovitz, J. (2019). Power to the people?! Twitter discussions on (educational) policy processes (pp. 231–244).
<https://doi.org/10.4324/9780429056826-18>

- Rehm, M., Moukarzel, S., Daly, A. J., & Fresno, M. del. (2021). Exploring online social networks of school leaders in times of COVID-19. *British Journal of Educational Technology*, n/a(n/a), 1–20. <https://doi.org/10.1111/bjet.13099>
- Rodway, J., MacGregor, S., Daly, A., Liou, Y.-H., Yonezawa, S., & Pollock, M. (2021). A network case of knowledge brokering. *Journal of Professional Capital and Community*, 6(2), 148–163. <https://doi.org/10.1108/JPCC-11-2020-0089>
- Schuster, J., & Kolleck, N. (2021). Education in times of global crisis: How private actors in Germany gain power through Twitter. *Education Policy Analysis Archives*, 29, 161. <https://doi.org/10.14507/epaa.29.6741>
- Supovitz, J. A., Daly, A. J., & del Fresno, M. (2015). #CommonCore: How social media is changing the politics of education. Consortium for Policy Research in Education. <https://repository.upenn.edu/hashtagcommoncore/1/>
- Supovitz, J., Daly, A., & Del-Fresno-García, M. (2018). The Common Core debate on Twitter and the rise of the activist public. *Journal of Educational Change*, 19, 1–22. <https://doi.org/10.1007/s10833-018-9327-2>
- Tasselli, S., Zappa, P., & Lomi, A. (2020). Bridging cultural holes in organizations: The dynamic structure of social networks and organizational vocabularies within and across subunits. *Organization Science*, 31(5), 1292–1312. <https://doi.org/10.1287/orsc.2019.1352>
- Timotheou, S., Miliou, O., Dimitriadis, Y., Villagrà Sobrino, S., Giannoutsou, N., Cachia, R., Martínez Monés, A., & Ioannou, A. (2023). *Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. Education and Information Technologies*, 28(6), 6695–6726. <https://doi.org/10.1007/s10639-022-11431-8>
- Tseng, V. (2012). The uses of research in policy and practice. *Social Policy Report*, 26(2), 1–24. <https://doi.org/10.1002/j.2379-3988.2012.tb00071.x>
- Trust, T., Krutka, D. G., & Carpenter, J. P. (2016). “Together we are better”: Professional learning networks for teachers. *Computers & Education*, 102, 15–34. <https://doi.org/10.1016/j.compedu.2016.06.007>
- Twitter. (2019). Home [Social media platform]. Twitter. Retrieved from <https://twitter.com>
- Valente, T. W. (1996). Social network thresholds in the diffusion of innovations. *Social Networks*.

- Veletsianos, G. (2020). *Learning online: The student experience*. Johns Hopkins University Press.
- Veletsianos, G. (2017). *Three cases of hashtags used as learning communities*. *TechTrends*, 61(3), 284–292. <https://doi.org/10.1007/s11528-016-0143-3>
- Wasserman, S., & Faust, K. (1994). *Social network analysis: Methods and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511815478>
- Weber, M. S., & Yanovitzky, I. (2021). Knowledge brokers, networks, and the policymaking process. In M. S. Weber & I. Yanovitzky (Eds.), *Networks, knowledge brokers, and the public policymaking process* (pp. 1–30). Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-030-67041-4_1
- Web Scraper. (2021). Web scraper - Free web scraping. Chrome Web Store. Retrieved from <https://chromewebstore.google.com/detail/web-scraper-free-web-scraper/jnhgnonknehpejjnehlklipmbmhnl?hl=en&pli=1>
- Weller, K., Bruns, A., Burgess, J., Mahrt, M., & Puschmann, C. (2013). *Twitter and society*. <https://www.peterlang.com/document/1109452>
- X. (2025a). Premium features and benefits. X.com. <https://docs.x.com/resources/premium-features>
- X. (2025b). Counting characters in a post. X.com. <https://docs.x.com/resources/fundamentals/counting-characters>