

How issue entrepreneurs shape public discourse of controversial science: examining GMO discussion on a popular Chinese Q&A platform

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Abstract

Social media have become popular channels for sharing and discussing science issues. Drawing from the classic communication theory, Public Arena Model, this paper examines how issue entrepreneurs influenced the Chinese public's cognition of GMO, especially the role of celebrities and scientists in controversial science communication. To answer this question, we used the structural topic modeling method to examine public discussion about GMO on a popular Q&A site in China (Zhihu) from 2014 to 2019 ($N = 40,101$). In study 1, we investigated what the major themes of public discourse are about GMO and the evolution of these themes in general. In study 2, we investigated public discourse in a more specific context, an iconic event in China's GMO history, a debate between a TV celebrity and a scientist, to examine how two major issue entrepreneurs influenced what and how the public deliberated GMO. We found that the issue entrepreneurs' debate increased public discussion on the *science communication* aspect of GMO yet decreased public discussion on the *science* of GMO. Supporters of different entrepreneurs are divided in their attitudes and rhetoric toward GMO. These findings shed new light on how social media is a digital embodiment of the public arena where public deliberation about controversial science occur and evolve.

Keywords

Public engagement with science and technology; Public understanding of science and technology; Science and media

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Introduction

With the development of Information and Communication Technology (ICT), social media have become popular channels where people seek and discuss science issues [Brossard & Scheufele, 2013]. Leveraging social media is crucial for political and social elites to engage with public discourse. While some scholars argue that the Internet provides promising opportunities for public engagement with science [Z. Wang & Zhang, 2016; Wen & Wei, 2018], others raise concerns about

misinformation and manipulation [Scheufele & Krause, 2019]. Drawing from theories on the public arena model and issue evolution, this paper examines how controversial science has been discussed in the digital public arena in China. Although much literature argues that issue entrepreneurs can influence how issues evolve and sustain public attention, little is understood about the issue evolution of controversial science in the digital space, especially on those knowledge-sharing discussion forums. For instance, how does public discourse evolve on the Question and Answer (Q&A) discussion forum? How do issue entrepreneurs (e.g., scientists and journalists) shape the content of public discussion on controversial science issues? How do issue entrepreneurs shape how the public deliberate about controversial science issues? Moreover, most literature on public engagement with science was conducted in Western countries, with very few analyzing public discourse in non-Western contexts [Liang, Liu & Zhang, 2019].

This paper takes China as the context of inquiry. In China, social media is one major platform where science information is disseminated and discussed [Jin, Li, Zhong & Zhai, 2015]. Online public forums provide rich data for studying public discourse on science as well as how social elites influence public discourse. Some scholars noted that these platforms provide opportunities for social elites such as celebrities and scientists to shape public opinions [Scheitle & Ecklund, 2017] while others found limited interaction between scientists and the public [Bauer & Jensen, 2011].

We examined one of the most popular social media Q&A forums in China — Zhihu and studied a highly controversial science issue, genetically modified organism (GMO), which has continuously drawn public attention over the past ten years. Zhihu provides a rich time-series dataset to analyze public discourse of GMO. We presented two studies in this paper. In the first study, we examined in general what the major themes of public discourse are about GMOs and how these themes evolved. In the second study, we zoomed into the public discourse of GMO in a more specific context, an iconic celebrity-scientist debate. We investigated how these issue entrepreneurs influence what aspects the public tended to focus on when deliberating GMOs and how supporters for the celebrity vs. the scientist differed in their deliberation styles.

Issue entrepreneurs, public deliberation, and science communication

Issue entrepreneurs and the Public Arena Model

Issue entrepreneurs are individuals and groups (e.g., interest groups, politicians, social movement organizations, television producers, lawyers, and public relations specialists) who define and shape the evolution of social problems, not only in issue salience but also issue frames and public alignment with the frames [Hilgartner & Bosk, 1988]. In the classic communication model, the Public Arena Model, Hilgartner and Bosk [1988, p. 59] defined arenas as institutions or news media where “social problems are discussed, selected, defined, framed, dramatized, packaged, and presented to the public”. Several important features constitute public arenas. First, issues need to compete because public attention is a scarce resource. Second, “operatives” — the groups and individuals who publicly present social problems — compete by using innovative (communication) strategies such as drama, novel framing, or coupling facts with emotional rhetoric, to keep public attention. Some entrepreneurs are more like opinion leaders that

focus on communication strategies while others are also activists that couple issue attention with policy and political window to move issues to the policy agenda [Kingdon, 1984]. Entrepreneurs differ in the resources they have (e.g., notoriety, expertise, and authority) and their goals also vary. To be an issue entrepreneur, one needs to have recognized credentials to gain a standing of the issue, and their voices or preferred frames need to be represented by the media [Ferree, Gamson, Gerhards & Rucht, 2002]. The public arena model has been applied in political and science communication to examine what communication strategies and resources entrepreneurs need to gain standing and frame the collective definition of a social problem.

In political communication, scholars examined the life cycles of social issues [Downs, 1972] and noted that only some have a long-life cycle where they develop, thrive, and sometimes sustain in public attention over many years [Carmines & Stimson, 1989]. Similar to Hilgartner and Bosk who stressed the role of issue entrepreneurs in deciding the life cycle of various issues, Carmines and Stimson also flagged that issue entrepreneurs, in the political context, strategic politicians, play the most influential role in determining the competition between issues. Through creating a clear party image and polarizing mass affection toward them, these strategic entrepreneurs have shaped the issue alignment between the mass public and elites [Carmines & Stimson, 1986]. In recent works on issue entrepreneurship and issue evolution, Hobolt and de Vries [2015] found that strategic politicians brought an issue to public attention by highlighting a previously ignored issue that differs from the mainstream status quo.

In science communication, scholars also started to examine who the issue entrepreneurs are. G. Yang [2010] identified four types of issue entrepreneurs in the creation of public issues of environment and health in China: media professionals, environmental and health NGOs, villagers, and netizens. As Yang noted, in the context of China, not every issue can be discussed due to political constraints. Issue evolution also depends on the resources and strategies these issue entrepreneurs have. For instance, social media is an alternative media channel where we observed Internet incidents happening frequently where Chinese netizens speak out on issues that resonate with the public. Strategies used by issue entrepreneurs are important for the issue evolution of science [Xu, Yu & Song, 2018]. Studying how individuals engage with opinion leaders on Weibo, a popular social media platform, Xu and her colleagues found that users are more likely to repost opinion leaders' messages about GMOs that used the fact frame.

Social media as a new public arena for discussing controversial science issues

Social media is a new public arena where issue entrepreneurs steer the evolution of public discourse in topics from politics [Shafer, 2017; Metzgar & Maruggi, 2009], to social justice [Byrne, 2007], and science debates [Boulianne, Lalancette & Ilkiw, 2020]. The advent of social media has not only created multiple channels of information with varying degrees and foundations of credibility for users but also democratized the opportunity structure for issue entrepreneurs with varying legitimacy claims to influence public discourses on controversial issues. Issue entrepreneurs in these social media movements vary from politicians to disadvantaged groups in our society, to citizen opinion leaders, scientists, or any ordinary citizens that post incidental videos and images that go viral.

This changing configuration of the arena on social media for information sharing brings unique opportunities and challenges to science-based issues. On one hand, it broadens the opportunity structure for members of the public to engage in discussions on science. This widened participation can provide valuable layperson knowledge for policymaking [Chen, 2021; Kerr, Cunningham-Burley & Amos, 1998]. For instance, social media platforms such as YouTube have facilitated a participatory culture for citizen scientists to share information in addition to professional content producers such as the legacy media [Burgess & Green, 2018]. On the other hand, the changing configuration also poses challenges to the epistemic authority of the scientific community and science, when more and more alternative venues join the platform to claim knowledge and defy the epistemic values of truth and liberty [Lewis, 2018]. Consequently, distorted and false information has spread on social media [Allgaier, 2019].

Like the issue entrepreneurs in the offline public arenas, social media reward strategic communications that are highly skillful in creating the drama of an event or topic. These skills in dramatizing events have a greater potency on social media than offline arenas as there is just too much information on social media to draw public attention. To shape the evolution of public discourse online, issue entrepreneurs need to craft their communication strategies through using drama, novel framing, challenging mainstream authority, storytelling, effective images, staging cameras, and videos to create conflicts, uncertainties, risks, fear, or entertainment to catch and sustain public attention.

Zhihu as a public arena for discussing controversial science in China

With social media becoming a public arena for science information, scholars have recently started to use social media platforms as an important research site for examining science communication. For instance, Xu et al. [2018] studied how individuals engage with opinion leaders on Weibo, a popular social media platform. Using the engagement metrics — likes, comments, and reposts, the authors found that source attribute and message frames influence user engagement. In addition to studying the effect of opinion leaders, scholars also investigated to what extent scientists in China use social media platforms to engage with the public. Conducting a qualitative interview with 25 Chinese scientists active on social media, Jia, Wang, Miao and Zhu [2017] found that Chinese scientists have not yet engaged in dialogue-based science communication with the public on social media.

Among different social media platforms for discussing and spreading controversial science, Zhihu is one such social media platform with a unique reporting and discussion structure. It is a site where discursive events occur, and expressions and engagements are stored. Zhihu is a concrete example of public arena that focuses on discussing science topics. As one of the most popular Q&A platforms in China, Zhihu allows users to contribute knowledge to online communities by asking and answering questions, commenting, and voting for each other's answers [Jin et al., 2015; Z. Wang & Zhang, 2016]. Platforms like Zhihu enable lay audiences to engage with a seemingly limitless amount of information from a wide range of sources in ways that are not possible through traditional media.

As G. Wang, Gill, Mohanlal, Zheng and Zhao [2013] pointed out, social media Q&A sites can draw the participation of both specific domain experts and a rapidly growing lay citizen population. The first and foremost feature of Zhihu is its knowledge-sharing mechanism which stresses the use of evidence. Commonly perceived as a high-end knowledge-sharing community, Zhihu is widely praised for its rigorous standard of the top voted answers in science topics [Zhang, 2018]. Liang et al. [2019] noted that the “evidence use” writing style can distinguish scientists from laypeople on Zhihu. The second feature of Zhihu lies in the close connection between what the public discuss on this platform and what happen in the news. The newsfeed feature in Zhihu encourages users to post and answer questions that highly correspond to issue entrepreneurs’ speeches and social events. Zhihu users receive newsfeed in three ways: 1) questions/answers/topics that their friends participate, 2) questions in the same topic they follow, and 3) answers in the question they follow. The newsfeed mechanism enables the issue entrepreneurs to draw the attention of Zhihu users efficiently.

More recently, like other social media platforms, Zhihu utilizes the recommendation algorithm to expose related content to potential readers. Given that celebrity participation news generally is preferred by social media readers [Kwon, 2019], the issue entrepreneur, if regarded as a celebrity at the same time, can facilitate the viral spread of related news. Lots of controversial issues in China, such as air pollution [F. Yang, 2016] and gender politics [Peng, Cummings & Li, 2022] were first discussed on Zhihu before reaching a broader public attention. In Figure 1, we present a typical question and answer structure on Zhihu, where users share their knowledge about the safety of GMO.

As a result of its knowledge sharing and discursive feature, Zhihu provides researchers with rich time-series data on the discursive traces to study how (science) issues evolved and how issue entrepreneurs, varying in their communication strategies, shaped the public discourse. For instance, GMO is one of the issues that has resided on Zhihu for a sustained period (nearly 8 years) and

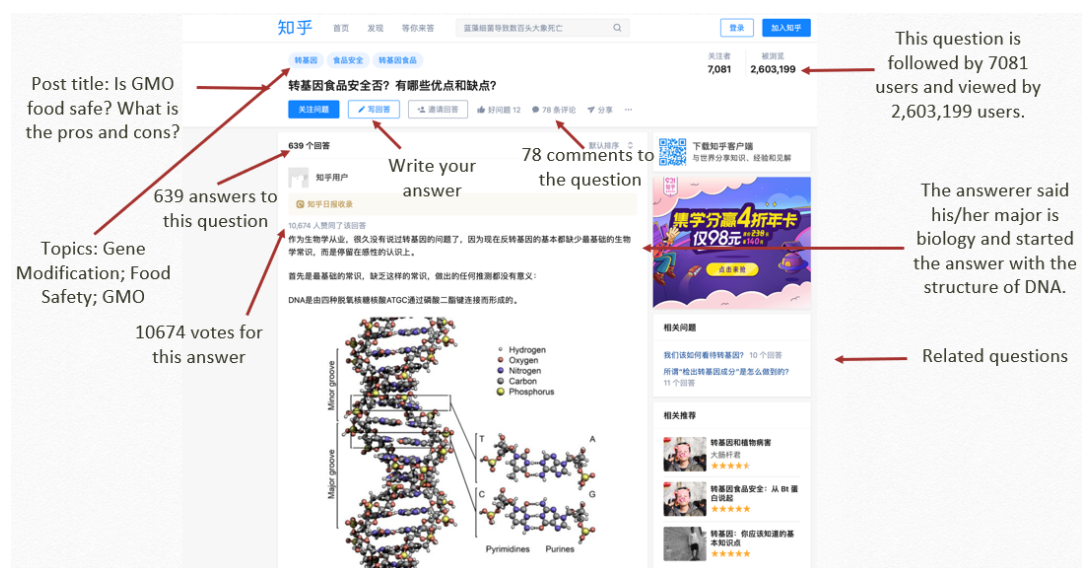


Figure 1. The discursive features of the Zhihu Q&A platform.

is one of the most controversial science issues that has been constantly discussed by media and the public since 2012. During the evolution, several debates occurred between a celebrity anti-GMO activist, an active science communicator, and a reputable scientist with impeccable scientific credentials (for details, see supplementary material, appendix III). These GMO issue entrepreneurs differed in their credentials and provided an excellent case to examine how celebrity status, likeability, and well-honed skills in dramatization would trump scientific rigor and epistemic authority in shaping public discussion. User-expressed opinions in Q&A's on Zhihu concerning GMO supply us rare rich data to examine the relative impacts of various issue entrepreneurs (e.g., celebrity and scientific authorities) in shaping public understanding of controversial science. As Hilgartner and Bosk [1988, pp. 73–74] stressed, to understand the effects of issue entrepreneurs in public discourse, “a time-series data to examine the share of resources each manages to capture... research could explore the timing of shifts in the focus of each individual’s activity from one problem to another”. This time-series rich dataset allows researchers to systemically study the diversity of problems discussed in the public arena [Hilgartner & Bosk, 1988].

To systemically examine the evolution of public discourse of GMO on Zhihu and how issue entrepreneurs influence the evolution of public discourse, we performed two studies. In *study 1*, we analyzed what the major themes of public discussions are about GMO on Zhihu and how these themes have evolved over the past six years (RQ1). In *study 2*, we zoomed into a specific context, an iconic debate of GMO in China (i.e., the Cui-Lu debate), and analyzed how the debate between the two issue entrepreneurs influenced what Zhihu users deliberated about GMO (RQ2). Under *study 2*, we also compared how Cui’s supporters versus Lu’s supporters differ in their opinions toward GMO and in their deliberation styles (RQ3).

Data and method

Data collection

We collected all GMO-related answers and their votes by using the Zhihu web crawler API in three steps. We started with the search term GMO and obtained 20 GMO-related topics returned by the Zhihu API (e.g., Genetically Modified Foods (GMF), Genetically Modified Rice, GM technology). For these 20 topics, we manually checked and found only the first 10 topics were highly GMO related (for details, see supplementary material appendix II). Then we used the web crawler API to collect all questions in these 10 topics and finally all answers to these questions. As of September 2019, we collected 4,326 questions posted by more than 2,230 unique users and 40,101 answers posted by more than 21,422 unique users since 2014.¹

Integrating computational and qualitative discourse analysis

Study 1. We applied the state-of-art structural topic model (STM) [Roberts, Stewart & Tingley, 2019] to examine the major themes users discussed on Zhihu over the past six years about GMO, and how these discussions evolved in terms of its

¹Although the Zhihu platform was launched in 2011, public registration was not available until 2013. Thus, we cannot find many GMO related posts before 2014 (there can be no GMO related posts for months). Considering we are most interested in the public discussion of GMO on social media, we only focused on the posts after 2014 when everyone began to have access to voicing their opinions.

prevalence over time (RQ1). Topic modeling is a statistical and computational technique for discerning information about the contents of a large corpus of documents that are typically unstructured [Blei, Carin & Dunson, 2010]. STM is a prominent example of topic modeling in computational text analysis and is designed for social scientists to move beyond exploration and make inferences about social and political processes that drive discourse and content. In this model, topical prevalence and topical content are specified as a simple generalized linear model on document-level covariates [Roberts, Stewart & Airolidi, 2016]. A topic in STM is defined as a mixture of words, and the topical prevalence refers to how much of a document is associated with a topic [Roberts et al., 2019]. To interpret the topics generated by STM, several researchers read the keywords and the highly associated answers of each topic to interpret the model output. Moreover, STM also allows researchers to examine how a topic's prevalence (i.e., frequency) changes over time by modeling topical prevalence as a function of document metadata. In our case, to study how topics evolved in terms of their prevalence, the metadata (independent variable) we used is the time when a post was posted. And the dependent variable is the post content.

Study 2. To answer the two research questions under study 2, we first studied how issue entrepreneurs' debate influenced public discussion of GMO. We examined an iconic debate happened on March 25, 2015 between a popular TV host named Yongyuan Cui and a professor of Genetics named Daru Lu. On that day, Cui held a public lecture at Fudan University, talking about his understanding about GMO. During the middle of the event, Lu who worked at Fudan University ran to the auditorium hall after a business trip and started a fierce debate with Cui centering around issues about the science and the social needs of GMO (for a summary of their arguments, see supplementary material appendix VI). Lu was the Associate Dean of the Biology Department at Fudan University and planned to hold another GMO related science lecture in April 2015. We collected the minutes of the March 2015 debate and summarized the main arguments from each. We then applied the structural topic model (STM) [Roberts et al., 2019] to compare the main themes Zhihu users discussed within a window of one month before and after the debate² using the `estimateEffect()` function from the `stm` package to investigate how entrepreneurs' debate shaped what aspects of GMOs the users focused on discussing. Since the goal is to detect the change of public discussion before and after the debate, we conditioned both topic content and topical prevalence on the dummy time covariate "Td" in the STM modeling. Td=1 means an answer was written after the debate and Td=0 means an answer was written before the debate. The metadata for Cui-Lu debate was collected from 2015-02-26 to 2015-04-25. We set the cut-off date 2015-03-26 because this was the date when the debate happened. Period 1 (Td=0) is the 1-month window before the debate and Period 2 (Td=1) is the 1-month window after the debate.

To answer our second research question in study 2 regarding how Cui's supporters versus Lu's supporters differ in their opinions toward GMO and in their deliberation styles, we conducted an in-depth qualitative content analysis of a sample of answers that Lu's supporters and Cui's supporters posted after the entrepreneurs' debate.

²We also examined different time windows (two months and three months) after the debate and found that there are no significant topics differences 2 months after the debate. This suggests that the effect of issue entrepreneurs' debate on public discourse might not be enduring.

To understand how Zhihu users discussed the Cui-Lu (i.e., scientist-journalist) debate, we focused on answers attached to a Zhihu question posted just after the event, “How do you think about the fierce debate between Yongyuan Cui and Professor Daru Lu on GM issues at Fudan University?” It was one of the most popular questions on Zhihu GMO topics and had received 1684 answers at the time of data collection. We manually coded all the corresponding 275 answers that received at least 1 vote and were posted in March and April 2015. These answers can best represent Zhihu users’ attitudes from three perspectives: 1) they were written just after the Cui-Lu debate, 2) they responded to the most popular question that time, and 3) they received at least 1 vote, indicating that these answers are endorsed by other users [Chen, Jin & Shao, 2022]. Under Zhihu’s mechanism of what answers show up on a user’s timeline, an answer without votes is less likely to be shown in the timeline of other users who look for answers to a question, while a voted answer will be more likely to be broadcast to more users (e.g., in voter’s timeline there will be a sentence that “V1 agree with A1’s answer in question Q1”, where V1, A1 and Q1 is the name of voter, answerer and question respectively). Through this mechanism, the voted answers can be further viewed by voter’s followers and are not limited to the answerer’s followers in the case of unvoted answers. Because of this endorsement mechanism, we chose to focus on analyzing these 275 answers as these answers were viewed by more users.

Three aspects were coded:

- Opinion alignment: whether an answer supports Lu’s discourse, supports Cui’s discourse, supports both or supports neither.
- Attitudes on GMO: whether an answer expressed attitude on GMO as support, oppose, or neutral.
- Deliberation styles the answerer used: no reasoning, narrative, citing facts, sarcasm.³

For the deliberation styles, we drew upon literature in public deliberation [Meyers, Brashers & Hanner, 2000; Scollon, 2008] as well as used inductive coding to develop three categories. “No reasoning” means an answer did not give a reason for or against the issue. “Narrative” means the answer used the poster’s personal experience or what he/she heard over about others’ experience as evidence. “Citing facts” means the answer cited factual evidence. “Sarcasm” means the answer used irony to mock or convey contempt. Example answers users given for each rhetoric category are described in Table 1.⁴

³We expected some other common rhetoric skills that appeared in other media such as “insulting, trolling”, however we didn’t find answers with these two rhetoric types in public discourse of GMO on Zhihu. It might be that Zhihu is the platform for a relatively more educated populations and they rarely use vulgar words to attack others and are reluctant to troll.

⁴Before we coded all the answers, we conducted inter-coder agreement check between two coders on a sample of 275 answers along three major content analysis variables: whether an answer supported Cui or Lu’s arguments, the answerer’s attitude toward GMO (support, neutral, oppose), and deliberation styles used in an answer (i.e., no reasoning, storytelling, logical argument, sarcasm). The Krippendorff’s alpha for these three dimensions is 0.981, 0.953 and 0.936 respectively. For the disagreement answers, the two coders had an open discussion to resolve disagreement. More details can be found in supplementary material appendix VIII: the intercoder reliability table.

Table 1. Examples of deliberation styles.

	Example Answer from Zhihu	Chinese Translation
No Reasoning	Cui only did a good job in his talk show, and the show could only invite comedians. Academic? He is far away from qualified. I don't know why he had the courage to talk about genetic modification with others.	小崔只适合搞他的小崔说事，并且只邀请笑星来上节目。学术业？他真没资格。也不知道他哪来这么大勇气跟别人谈转基因。
Narrative	As a student of Mr. Lu ... So it is the case that Mr. Lu was not well prepared, he counted on his accumulating knowledge on ordinary days. Our laboratory does not specialize in Gene Modification...So when it came to the boring question of how many genes has been modified, Teacher Lu couldn't answer it immediately and accurately. After all, a scientist's literacy told him that he couldn't talk about uncertain things with certainty.	作为卢老师的学生.....所以要说是准备不充分，的确是这样，卢老师全靠平时积累。我们实验室平时也不是做转基因的.....所以说到几个基因这种无聊的问题，卢老师不能马上准确地答出，毕竟一个科学家的素养告诉他，不能信口雌黄，不确定的东西不能一口咬定。
Citing fact	How many genes did Golden Rice transfer? The answer is 3 in 1st generation and 2 in 2nd generations. The official website of the International Rice Research Institute (IRRI) found ... The first generation of golden rice in 1999 transferred two daffodil genes and one ctrl gene from a bacterium, so there are three in total. To be honest, anyone who has learned the principles of molecular biology or gene manipulation couldn't understand Cui's way to calculate gene.	黄金大米到底转了几个基因？答案是1代3个，2代2个。国际水稻研究所(IRRI)的官网上查到.....1999年的第一代黄金大米转入了两个黄水仙(daffodil)中的基因，以及一个细菌中的ctrl，所以一共是三个。说实话任何一个学过分子生物学或者基因操作原理的人都想不到小崔会这么算“基因”吧。”
Sarcasm	The long-time insufficient sleep does have a serious negative impact on his brain...	长期睡眠不足确实会对大脑产生严重的负面影响.....

Results

Study 1: major themes and evolution of public discourse on GMO

This part presented our findings for study 1 that examines the major themes of public discourse of GMO on Zhihu and how these themes evolved over the past six years (RQ1).

We found three major themes that have been prevalently discussed on Zhihu regarding GMO. As Figure 2 shows, topic 1, 4, and 5 constituted the major proportions of public discussions. We examined the keywords and example answers under each topic. Topic 1, which consisted of 20% of all discussions of GMO on Zhihu, is about public discussions on the safety concerns of GMO food, especially whether it is safe to eat and whether GMO food can result in health problems. The second theme centers around public discussion on issue entrepreneurs' perspectives on GMO such as how famous journalists, TV hosts, and scientists debated about GMO (topic 4). The third major theme centers around how scientists and the lay public perceive the safety issues of GMO differently (topic 5). Under this theme, users highlighted the differences in scientists' perception vs. lay citizens' perception of the risks of GMO food. Users raised distrust of scientists to inform public about the safety of GMO. Topics that have been less frequently discussed are how people in other countries perceive the safety of GMO (e.g., topic 2, topic 3).

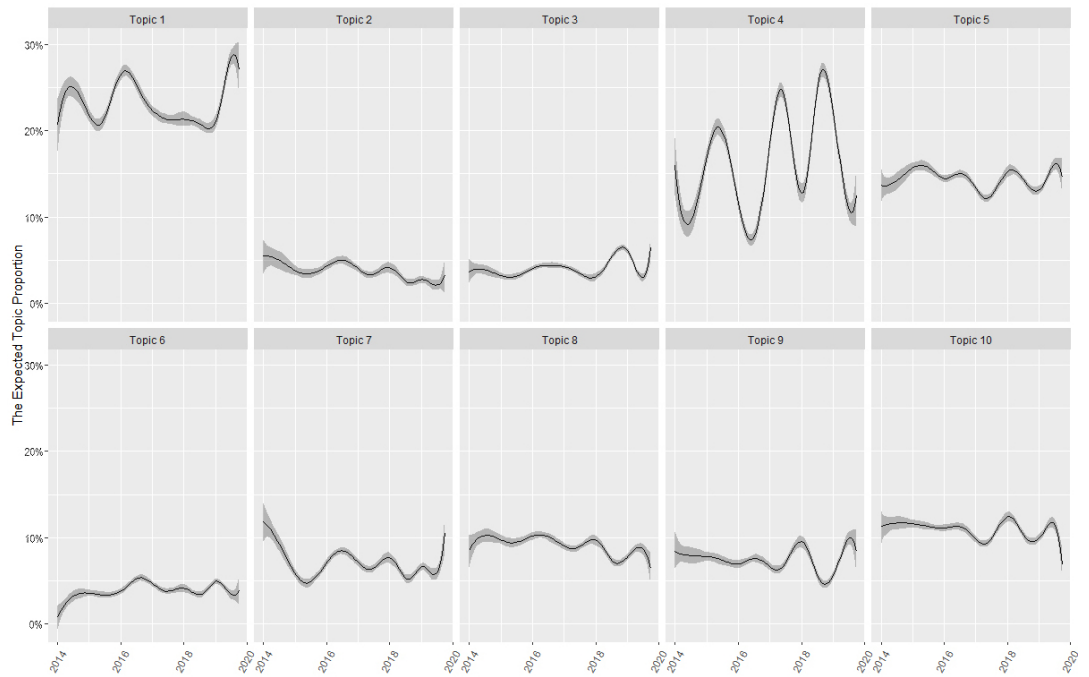


Figure 2. Public discourse about GMO: major themes and their evolution on Zhihu (2014–2019).

Examining the evolution of how different themes of public discourse changed over time (from 2014 to 2020), we found that interestingly, the three major themes (topic 1, 4, and 5) experienced many more fluctuations in terms of their frequency of being discussed compared to other non-prevalent themes. To further investigate when public discourse reached peaks during the past six years, we calculated for each month, the number of questions users raised about GMO, the number of answers users posted, and the number of votes users cast on the answers. Figure 3 showed that there were three peaks where the number of questions, answers, and votes all reached the highest.⁵ Looking into what users discussed during these peaks, all of them corresponded to the important social events initiated by the GMO issue entrepreneurs. The first peak happened following an iconic debate between a TV host and a scientist at a famous Chinese University (2015-03-26); the second peak happened when the TV host opened his online organic food store Puguton (2017-05-20); the third peak occurred when the TV host revealed other celebrities' tax evasion (2018-05-25). It is noteworthy that the third peak is unrelated to the topic of GMO. Yet, since the entrepreneur involved is an anti-GMO activist, users drew attention to other events he organized.

⁵We may notice that there is another question peak toward the end of 2015, but we did not consider it as the peak refers to where the number of questions, answers and votes all reached the highest. At the end of 2015, Cui started to cyberbully some netizens on Chinese social media, so these netizens, along with their schoolmates and friends, started to post questions such as "How do you feel about Cui's cyberbullying on XX". However, this event did not attract much public attraction, as we find that 1) the number of votes of related posts at that time is low (the bottom panel in Figure 3), which indicates that these posts were not viewed and broadcasted to most users, 2) although the number of answers seemed high, proportionally speaking, the average number of answers for each question is quite low, which again indicates this discussion did not attract many answerers.

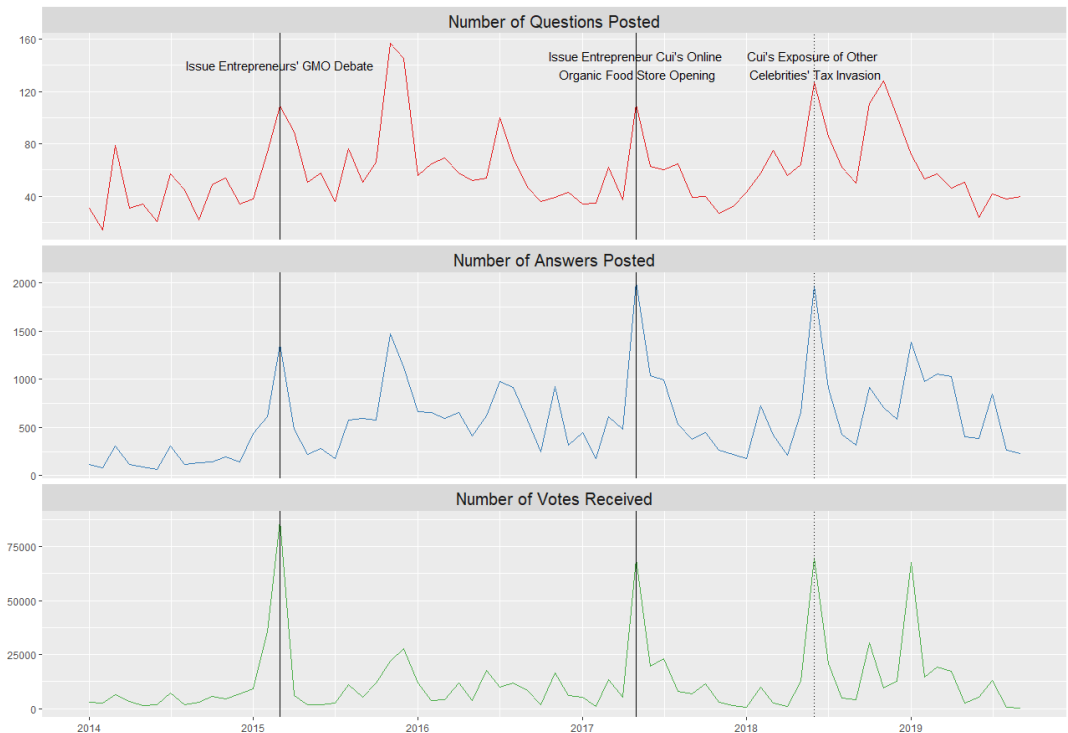


Figure 3. Spikes of question, answers, and digital votes (2014–2019).

Study 2: comparing public discourse before and after the TV celebrity-scientist debate

In our study 2, we took an in-depth examination of the first peak, the most iconic event in GMO history in China, the Cui-Lu debate. For this debate, one key issue entrepreneur is a famous TV host Cui Yongyuan. His discourse and engagement on GMO have drawn waves of public attention since 2013. As time went by, he chose emotional rhetoric as his strategies to question the scientific authority of GMO and used offensive and aggressive language. All these arguments reached a climax during his speech at Fudan University on March 26th, 2015.

Table 2 summarizes the main arguments from these two issue entrepreneurs, the communication styles they used, and an example dialogue to illustrate their debate. Lu stressed the science of the safety of GMF by pointing out that GMF was well testified by the science community and some GMF such as golden rice had proved to benefit the society these days. Different from using scientific evidence and reasoning, Cui continued his emotional rhetoric strategies, challenging the political authority and the science community.

Discussion shifted from science of GMO to science communication of GMO.

Comparing what the major themes are from users' posts before vs. after the Cui-Lu debate (RQ2), we found that there was an increase in public discussion about science communication of GMO but a decrease in public discussion about the science aspects of GMO such as safety.

Figure 4 shows the effect of Cui-Lu debate on topic prevalence for the top ten prevalent topics Zhihu users discussed. The point estimate is the mean effect of the debate, and the lines are 95% confidence intervals. If the estimate and its

Table 2. Cui-Lu debate: communication styles, major arguments, and an example dialogue.

Issue	Major Arguments	Communication Styles	An Example Dialogue
Entrepreneurs Cui Yongyuan	1. Science community cannot represent the interests of the public 2. Questioned Lu's ability because Lu cannot answer Cui's misleading question 3. Challenged the authority of Lu as a genetics professor and the science community Lu represents.	1.Challenged the political authority by unverified evidence 2.Asked misleading questions 3.Argued with aggression and mocked the opponent 4.Incited audience's emotions	Lu: Although the golden rice's Chinese trail breached the informed-consent form, we should be aware of its economic and healthy benefit to blind children in developing countries. Cui: As we talked about golden rice, let me ask you, how many genes have been modified in golden rice? Lu: It can be two, or one? It depends on the version and whether you count on the metabolic enzymes... Cui: Are you kidding me? You are a professor! How can you guarantee it is safe without knowing how many genes have been modified?
Lu Daru	1. We should not demonize GMO 2. Criticized Cui's ambiguous and misleading personal statements about GMO	1.Cited facts 2.Utilized scientific reasoning 3.Argued with calm during the debate 4.No interaction with the audience	

confidence interval cross the vertical zero line, then the Cui-Lu debate does not affect the proportions of answers focused on this particular topic. Estimates above zero are topics that are more likely to be discussed after the debate. Estimates below zero are those less likely to be discussed after the debate. Figure 4 suggests

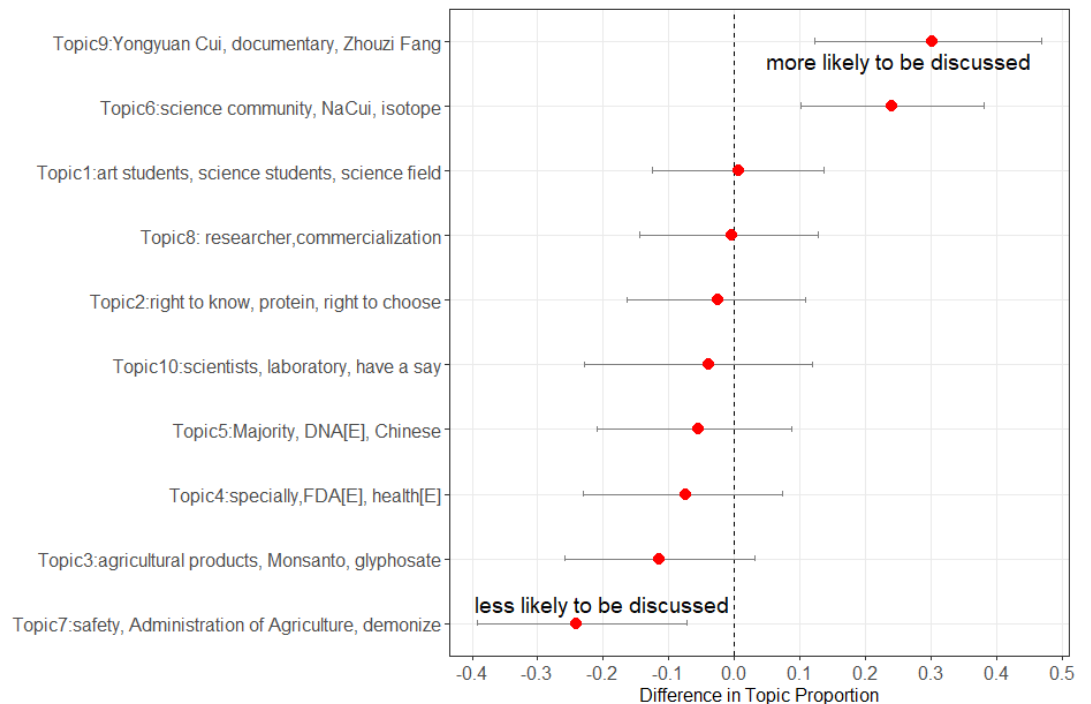


Figure 4. Effect of Cui-Lu debate on the topic prevalence of public discussion, with mean and 95% confidence intervals.

that the debate significantly increased the likelihood of Zhihu users to discuss topic 9 and topic 6 and significantly decreased the likelihood to discuss topic 7. We further examined what these 3 statistically significant different topics are by reading the most associated answers for each topic.

Topic 9 is about public discussion on entrepreneurs' communication skills with keywords "Yongyuan Cui, documentary, Zhouzi Fang, journalism, host". This topic is 30% more likely to be discussed after the Cui-Lu debate. Lu's perceived failure reminds people of "Zhouzi Fang", a science communicator who had debated with Cui before. Highly voted answers also indicated that many Zhihu users felt sorry for Lu's insufficient debate training in facing Cui, and some answers pointed out that "ironically only Fang can deal with Cui".

Topic 6 is about public discussion on the conflicting viewpoints on GMOs between the journalist community and the science community with the keywords "science community, NaCui (Sodium Cui), isotope". This topic is 23% more likely to be discussed after the debate according to our estimation. Cui once criticized that golden rice in China was irrigated with deuterioxide, which turned out that the "isotope" deuterium was just used to track the carotene in experiments and was too expensive to be applied in industry. Thus, people took it as proof that Cui demonized GMOs. Cui had posted a Weibo regarding NaCl as some toxic element and thus it got the nickname "NaCui" (Sodium Cui) because he didn't know NaCl is the chemical formula for salt. In this topic, people used this nickname to indicate that Cui, as a TV host and journalist, was not qualified to debate with Lu who was from the "science community". This conflict between the scientist and the journalist community is a projection of the Cui-Lu debate where the most fiercely debated part is about who is qualified to communicate science.

Topic 7 is about public discussion on the safety of GMO with keywords "safety, Administration of Agriculture, demonize", and it is 25% less likely to be discussed after the Cui-Lu debate. Discussions within this topic pointed out that the lay public should not have confidence in the "safety" of GMO unless the experts fed their offspring with GMO. The distrust in "Administration of Agriculture" and the "safety" issues of GMO was Cui's long-time discourse themes and was criticized fiercely by Professor Lu during the debate and science communicators also stressed that Cui should not "demonize" GMO.

In summary, the comparison between what the public discussed before and after the Cui-Lu debate suggests that public discourse is highly affected by the issue entrepreneurs' dramatization of the issue (i.e., debate), which is expected. What is more interesting is that public discourse shifted to focusing more on the *science communication* surrounding GMO, rather than the *science* related to GMO. These communication aspects include people's discussion on the divergence in opinions of GMO between celebrities and scientists and the enduring conflict between the journalist community and the science community. The scientists' ineffective communication skills compared to the journalists were stressed a lot by the Zhihu users. In contrast, the science-related aspects of GMO, such as the science fundamentals and safety of GMO, drew even less attention from the public after the debate.

A divide in opinions toward GMO and in deliberation styles between TV host's supporters versus the scientist's supporters. To further examine how users' opinion toward GMO differed between those who supported Lu vs. Cui, and the differences in the deliberation styles used by Cui vs. Lu supporters (RQ3), we reported here the findings of our qualitative content analysis of the answers Zhihu users posted to the question on the debate. First, examining which side public discourse leaned towards, we found that among our hand-coded 275 answers, 100 expressed their attitudes on the two issue entrepreneurs explicitly, among which a half (54%) supported the scientist, and a half (46%) supported the celebrity. The 11 answers with the highest votes in our dataset (votes range from 23,819 to 978) all supported scientist Lu's arguments on GMO, and none opposed GMO. Since the vote is the indicator for popularity on Zhihu, this suggests that Zhihu users gave more credit to answers that aligned with the scientist's viewpoints of GMO, even though Lu lost the debate and other social media platforms (e.g., NetEase News and YouTube) were pro-Cui.

We then investigated among the users who have different opinion alignments with issue entrepreneurs, how their attitudes toward GMO differ, and how their rhetoric of deliberating GMO differs. As the top panel in Figure 5 shows, none of the Cui-supporters expressed positive attitudes towards GMO and none of the Lu-supporters rebuked GMO. This divergence between the "journalism community" and the "scientific community" in elites' discourse recurred in the public discourse, where the difference between liberal arts vs. science majors at the university was discussed fiercely. It also echoed previous literature that stresses public discourse is always and inherently political [Scollon, 2008].

In terms of the deliberation styles used by the supporters from different entrepreneurs (bottom panel in Figure 5), we also found an interesting difference between the Cui supporters and the Lu supporters. Citing facts were much more prevalent among people that supported the TV host Cui (85%)'s arguments than those who supported the scientist Lu (54%)'s. Recall that the majority of Zhihu users disliked Cui, and it forced Cui's fans to argue with more reasons to justify they were not the unreasonable liberal arts student as described in some popular answers. The minorities are often defensive against a unified majority offense, and they tend to use different argument messages [Meyers et al., 2000]. The Cui-supporters on Zhihu were pressured to cite many facts to defend that their opposition to GMO did not result from the inferior education level or insufficient critical thinking abilities.

The use of narrative was more common among people supporting the scientist Lu (28%). Some Lu-supporters were biology students or scientists in related fields who defended with their personal stories. They used personal experiences to illustrate that Lu was defeated in the debate due to lack of debating skills training, not because Cui's arguments were more convincing than Lu's. They criticized that Cui took advantage of Lu's clumsy speech skills as a scientist.

Another phenomenon corresponding to the scientist-favored environment on Zhihu was the sarcastic answers created by Lu's supporters. The practice of sarcasm requires that the hearer shares enough pragmatic knowledge to comprehend what speakers mean by what they say [Gibbs, 1986]. Most sarcastic answers opposed Cui and made funny stories mocking Cui's discourses.



Figure 5. How the scientist’s supporters vs. the TV host’s supporters differ in their GMO attitude and deliberation styles.

Discussion and implications

Our paper examines how social media is an exemplar public arena for issue entrepreneurs to shape public discourse, a classic question that has been extensively studied in the offline communication settings but is less understood in the digital space. Issue entrepreneurs in the offline public arena model are often political entrepreneurs, scientists, or those who possess more resources and status in society. Social media democratize the opportunities for a more diverse group of issue entrepreneurs to shape public discourse. Especially noteworthy is the interaction between scientists, celebrities, and the lay public, with some having more expertise on the topic while others hold alternative views toward the science topic. This interplay among different actors on social media provides an excellent opportunity for researchers to investigate how communication strategies (such as challenging scientific authority vs. using science, monetization of science issues) can influence what and how the public discuss controversial science issues. Both the content and the quality of public talk are crucial outcomes to examine the role of issue entrepreneurs in public discourse [Ferree et al., 2002].

Our paper provides new knowledge about the role of issue entrepreneurs in public deliberation of controversial science in several manners. First, this study is one of the first to investigate how issue entrepreneurs can influence public discussion on a controversial science topic over time. Interestingly, we found that the debate did not increase people’s discussion on the science aspects of the science topic, but rather on the science communication aspects of the topic. For instance, people were more likely to discuss that the science community should communicate more effectively about science topics with the journalist community and the journalist

community needs to respect the science community and science. In addition to suggesting more effective communication between scientists and journalists, Zhihu users' behavior also suggested that scientists need to improve their ability to communicate science to lay audiences such as journalists and the public. These interesting findings echo literature that articulated the persistent challenges between the journalist community and science community on how to communicate science to the public [Dunwoody, 2014; Eide & Ottosen, 1994]. The findings also speak to the increasing call for training communication skills among scientists [Newman, 2019] and having more dialogues between scientists and the public [Jia et al., 2017].

Second, we contribute to literature on public engagement with science by studying not only what the public opinions are but how the public deliberate about their rationales for supporting different issue entrepreneurs' viewpoints. In the public arena model and its applications, issue alignment focuses more on how the content of public discourse aligns with entrepreneurs. In addition to examining the content, we also studied how the way public deliberate about an issue might align with how the entrepreneurs communicate about an issue. Although deliberative approach has been practiced to improving science communication, little is known about how the public deliberate about science issues [Bächtiger, 2018]. We studied Zhihu users, a group of populations more interested in science issues than the lay publics. Different from Arnocky, Bozek, Dufort, Rybka and Hebert [2018] who found that participants accepted views from celebrities more than expert sources, we found that among the Zhihu users, half of them supported the journalist's discourse and half supported the scientist's discourse.

One noteworthy finding regarding how issue entrepreneurs' communication strategies might influence how the public deliberate about controversy is that unexpectedly, supporters of the journalist who used emotional rhetoric as the main way of communication tended to cite facts to argue for this issue entrepreneur. Yet, supporters of the scientist tended to use personal stories/experiences to argue for the merits of the scientist. This indicates that the journalist's defenders tried very hard to present themselves as critical thinkers, and the scientist's defenders tried to mention less about science but more about personal stories to persuade the other group. These nuances of public deliberation showed in this paper shed new light on how the public uses narratives, emotions, and logic in engaging with each other, a critical topic that is much less understood [Liang et al., 2019].

Moreover, this paper also brings new knowledge to our understanding of how social media provide a digital public sphere for science communication in the non-Western contexts. We joined a small but growing effort of studying public engagement with controversial issues in China. China as a research site could offer a methodological advantage to observe key science communication questions under a different social media ecology [Anderson, 2012; Jia et al., 2017]. This understanding will provide fruitful background information for researchers to conduct a cross-cultural analysis of science communication between Western contexts and the non-Western contexts and to expand science beyond the dominant Western languages and cultures [Márquez & Porras, 2020]. For instance, future research could investigate how macro-ICT systems influence the interaction between scientists, journalists, and the public.

Finally, this study demonstrates how researchers can use machine learning tools such as application programming interface and integrate human coding with computational content analyses to collect and analyze public discourse on a large-scale and over time, which is critical to understand the full range of online discussions [Liang et al., 2019]. As Xu et al. [2018, p. 711] suggested, “in addition to studying the quantitative aspect of engagement in the discussion of GMOs on social media, future researchers may conduct content analyses over the actual comments to explore how opinion leaders’ discourse affects the discourse of other social media users”. Hence, we extend this scholarly approach in this paper. We integrated manual content analysis with computational methods to analyze around 40,000 comments people posted on a social media platform about GMOs from 2014 to 2019. We showed how state-of-the-art computational content analysis methods such as STM allow researchers to compare public discourse changes before and after important events, and thus help us to answer crucial science communication research questions such as how changes in celebrity framing can reconstruct public discourse.

Limitation

Several cautions need to be taken when interpreting the generalizability of our paper’s findings. First, this paper examined a single social media platform. Users from this platform might be more interested in science topics compared to the lay public in China. Future studies can extend to investigate public discussion of GMO on other social media platforms to see how our findings might vary. Second, this paper offers an exploratory investigation into how public discourse differed before and after a celebrity-scientist debate. We do not suggest any causal relationships between celebrity influence and public opinion changes. Our findings can be further tested in experiment settings. For instance, scholars can assign people into the treatment condition to watch a celebrity-scientist debate and then let people discuss GMOs while having a control group to study whether findings from this paper still hold. Third, we also acknowledge that public discussion of GM foods might be different from GM technology. For instance, Chen and her co-authors [2022] examined GMO-related misinformation on Zhihu. They found that GM foods are mainly related to personal healthy misinformation while GM technologies are discussed with nationalism-infused misinformation such as gene weapons. This suggests that discourse initialized by GM technology might be more ideological and political compared to GM foods, an area which is worth exploring for understanding how to communicate science effectively to audiences for different GM-related issues.

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