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The Mathematical Mindsets and Mathematical Identities Revealed in Social Media Discourse

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ABSTRACT Mathematics problems are shared rapidly across all social media platforms, and the relative anonymity granted to users can lead to unfiltered discourse. This study examined 1,046 comments from a mathematics problem posted twice to YouTube in February 2016 to determine the underlying narratives that indicate the commenters' mathematical mindsets and their mathematical identities. These two factors contribute to mathematics success in general. Qualitative themes emerged regarding attributions, motivational goals, response to failure, defensive processing, normative comparisons, and positional acts. A fixed mathematical mindset was the dominant mindset and corresponded to positional acts of superiority, inferiority, or authority. This finding suggests that intellectual capacity or ranking was a core component of the mathematical identities for these users. The growth mathematical mindset was linked to spectator and instructor or solidarity positions, suggesting that these users had more robust mathematical identities that were unthreatened by performance indicators. Further examination of social media discourse and its relation to mathematical mindsets and mathematical identities can lead to a better understanding of the interactions outside the classroom that either encourage or inhibit mathematics success.

KEYWORDS *implicit theories of intelligence, mindsets, mathematical mindsets, mathematical identity, discourse, positional acts, social media*

Overview

Social Media

In January 2020, 4.5 billion people used the internet; of those users, 3.8 billion engaged in social media (Nazir & Dubras, 2020). The ubiquity of social media to daily life has resulted in digital footprints that are increasingly intertwined with social interactions that can render both beneficial and harmful changes to mental well-being. For instance, social media can beget positive health effects when it is used to facilitate actions that increase our social capital:

> Individuals who are members of a social network, as opposed to those who are not, have access to information, social support, and other resources such as other network members' skills and knowledge due to their network membership or social connections. (Bekalu et al., 2019, p. 69S – 70S)

As a result, some social media users have improved their mental health. For example, social media users have reported feeling a stronger sense of community and being more emotionally supported (Royal Society for Public Health, 2017). However, social media usage can also lead to harmful consequences by increasing adverse health effects, such as anxiety, depression, and poor sleeping patterns. In May 2017, the Royal Society for Public Health and the Young Health Movement surveyed 1,500 people aged 14-24 in the UK and found that four of the five most used social media platforms for their age demographic (Facebook, Instagram, Twitter, Snapchat, and YouTube) increased their feelings of anxiety and depression (Royal Society for Public Health, 2017). Of note, YouTube was the only social media platform to have shown a positive effect in this respect.

Mathematical Discourse and Implicit Theories of Intelligence

The relative anonymity afforded to social media users contributes to discourse that is often unfiltered (i.e., audacious and communicated without consideration to the audience). So, what happens when you introduce an innocuous mathematics problem to this nearly unbridled comment culture? On its own, mathematics discourse can be enlightening. Our response to a mathematics problem can manifest our implicit theory of intelligence, which Hong et al. (1995) describes as:

> Beliefs about the fundamental nature of intelligence, specifically whether intelligence is a fixed entity that cannot be changed (an entity theory) or a malleable quantity that can be increased through one's efforts (an incremental theory). (p.198)

Implicit theories of intelligence influence the motivational goal that we feel driven to pursue. Entity theorists actively seek performance goals; in their framework, a task's outcome measures their limited intellectual capacity. Incremental theorists value effort as a conduit for success; therefore, they embrace learning goals and are motivated by mastering new things. Notably, implicit theories of intelligence can be domain-specific (Yeager & Dweck, 2012) and can operate in tension with the generally held theory.

As we navigate cognitive challenges, we continuously seek confirmation of our beliefs about intelligence, an endeavor referred to as "theory protection" (Plaks et al., 2005). As a result, the receipt of negative feedback (or stereotype disconfirming information) will cause both types of theorists to exhibit defensive processing, with more observed on the part of the entity theorists (Plaks et al., 2001). Defensive processing can impact our receptiveness to retain new information. For instance, following negative feedback on tests of general knowledge, Mangels et al. (2006) found that students' beliefs and reactions to failure influenced their learning success by manipulating their attention and conceptual processing, two functions that serve to either inhibit or increase gains in knowledge. Two examples of defensive processing are defensive inattention (a form of passive defense involving partial encoding of, or selective attention to, challenging information) and intensified scrutiny (a form of active defense involving discounting or debunking challenging information). When defensive inattention is not possible, intensified scrutiny may be employed (Eagly et al., 1999; Eagly et al., 2000; Plaks et al., 2005).

Our perception of negative feedback and its role in confirming or disconfirming our implicit theories of intelligence varies. To the entity theorist, negative feedback equates to failure in intellectual ability. Given a high grade, the entity theorist will continue to receive high grades; however, given a low grade, they will continue to receive low grades for their poor performance is a testament to their low, fixed intelligence that cannot be improved (Grant & Dweck, 2003). This response to failure is known as the helpless pattern and is characterized by the feeling that failure is out of one's control. As a result, entity theorists make ability attributions (e.g., "I'm not smart enough.") and are more susceptible to loss of self-worth (Grant & Dweck, 2003). Additionally, there can be a normative comparison element to performance goals (i.e., a desire to outperform others), which may lead to a reluctance to perceive one's performance as a failure in the first place (Grant & Dweck, 2003). In this regard, entity theorists may engage in intensified scrutiny, such as devaluing the problem, to preserve their perceived rank.

Incremental theorists exhibit a healthier response to failure as it poses no threat to their intellectual capacity. After a poor performance, the incremental theorist will make effort attributions (e.g., "I need to study more.") and will likely persist to the point of improvement (Grant & Dweck, 2003). This response is coined the mastery-oriented pattern and is characterized by linking failure to modifiable factors, such as lack of effort (Diener & Dweck, 1980). As a result, they will seek positive interpretations and growth (Diener & Dweck, 1980; Farrell & Dweck, 1985; Grant & Dweck, 2003; Mangels et al., 2006), which will ultimately lead to more significant gains in knowledge (Grant & Dweck, 2003).

Unsurprisingly, entity theorists' maladaptive tendencies can affect self-esteem and, in the case of mathematics, lead to mathematics anxiety. These learners are more likely to equate genius with low effort, an attribution which encourages them to value speed—with respect to recall of facts, the time it takes to solve a problem, and the general brevity of all mathematics solutions—over effort. Unfortunately, the role of speed in mathematics is misrepresented in popular culture, much to the detriment of mathematical learning: when we equate skill with speed and value fast recall over deep conceptual understanding, mathematics anxiety increases, and creative inquiry declines (Boaler & Zoido, 2016).

Mathematical Discourse and Mathematical Identities

Several other misconceptions regarding mathematics are likewise promulgated by popular cultures, such as the various tropes that dominate our mental schemas regarding those characteristics that define a mathematician: the eccentric Einstein-like older man; the young, tortured genius; and the genetically different savant (Barba, 2018). Additionally, there is a "white male myth" regarding an innate proclivity for mathematics that permeates Western culture (Stinson, 2013). Not only does this myth exacerbate stereotype threat (e.g., race, gender), but it has been shown to impact the mathematics achievement of marginalized groups (Spencer et al., 1999; Steele, 1997; Steele & Aronson, 1995). These preconceived and developing notions that we have regarding mathematics and mathematicians shape our attitudes and preferences towards mathematics, two factors, of many, that contribute to one's mathematical identity.

Mathematical identity "can be broadly defined as participative, narrative, discursive, psychoanalytic or performative" (Darragh, 2016, p. 24). Theorists dispute its classification as conscious versus subconscious, independent versus interdependent, or an action versus an acquisition. Nonetheless, mathematical identity likely encompasses each of these attributes to some degree. In her examination of identity in mathematics education research, Darragh (2016) describes it as an adjustable lens through which a magnification reveals interactions on the individual scale and zooming out reveals interactions in a socio-political context. Then, she writes:

> We can look at the big picture, that is, at issues of mathematics learning in general. We can look at the experiences of specific groups of people and issues of equity. Or we can look at the individual level and try to understand learners' relationships with mathematics. (p. 20)

Regardless of the scale, social interactions are a critical element of mathematical identity. Thus, mathematical identities are developed and enforced via mathematics socialization through exchanges within "communities of practice" (Wenger, 1998) or "figured worlds" (Boaler & Greeno, 2000; Holland et al., 1998). Martin (2012) describes mathematics socialization as referring to "the experiences that individuals and groups have within a variety of mathematical contexts … that legitimize or inhibit meaningful participation in mathematics" (p.57). Arguably, social media has emerged as a source of mathematical socialization through which (non)mathematical identities are fostered. According to Epstein et al. (2010), young people use the mathematical discourse circulated in popular culture to negotiate their own identity making. Therefore, discourse is not only an integral contributor but also a conduit for identity formation. Every occasion for communication enables participants to construct and negotiate their self-image and social position (Davies & Harré, 2001; Waring, 2018). This negotiation is a perpetual process: mathematical identities are the byproducts of constant, and often subconscious, adjustments made from exposure to various narratives such as racial, gender, cultural, historical, or political.

Furthermore, mathematical identity is revealed in discourse through the negotiation of positional actions. Positioning is the reciprocal and dynamic process through which roles are actively established, altered, and reestablished for those engaged in the interaction (Davies & Harré, 1990). According to Davies and Harré (2001), "Positions are identified in part by extracting the autobiographical aspects of a conversation … to find out how each conversant conceives of themselves and the other participants by seeing what position they take up" (p. 264). Furthermore, "an explicit positioning of self naturally involves an implicit positioning of other" and vice versa (Minow, 2012, p. 98). Therefore, mathematical identity can be interpreted as the "social positioning of self and other" in mathematics discourse (Bucholtz & Hall, 2005, p. 586). Finally, the relative anonymity of social media emboldens users who feel immune to repercussions; as a result, their discourse can devolve into audacious criticism of others. Consequently, positioning acts are more conspicuous and intensify as social interactions expand from one-to-one to one-to-millions.

Implicit Theories of Intelligence, Identities, and Positive Outcomes

According to Jetten et al. (2011), social interactions and identity can impact mental and physical health in a profound way. Extant studies have shown mathematical identity to be fundamental to the development of attitude, disposition, emotional well-being, and a general sense of self (Bishop, 2012). Additionally, mathematical identities are indicators of mathematical performance, persistence, and success (Cribbs et al., 2015). Implicit theories of intelligence have likewise been shown to be fundamental to academic success and linked with social interaction (e.g., adult feedback practices) (Blackwell et al., 2007; Plaks &

Stecher, 2007). For instance, incremental theorists receive higher grades, are reported to enjoy and value academics more, have increased motivation, choose more positive, effort-based responses to failure, are more resilient, demonstrate greater confidence, and experience greater overall gains than entity theorists (Aronson et al., 2002; Blackwell et al., 2007; Boaler, 2016; Dweck, 2016; Good et al., 2003).

However, studies have yet to show how social media interactions, primarily through written discourse, relate to implicit theories of intelligence and mathematical identities. Characterized by controversy, social media discourse surrounding mathematics problems is often a mélange of uninhibited reactions. Further, social media enables interaction among larger and more diverse groups of people. Therefore, it is important to view this particular form of discourse through a critical lens to determine the role it has in developing mathematical mindsets and identities, and its effect on positive outcomes, such as mathematics success.

Purpose of the Study

The purpose of this study was to examine the discourse in the comments section of social media posts regarding a mathematics problem and analyze the underlying narratives which reveal the mathematical mindset and mathematical identity of each user.

Method

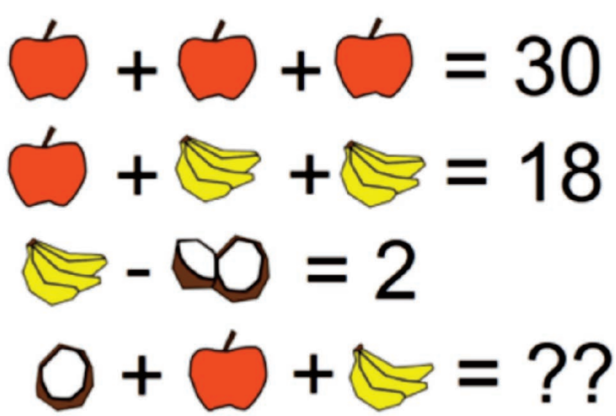
The current study focused on the discourse in the comments section of the same mathematics problem posted twice to YouTube in February 2016 (Figure 1). The mathematics problem was described as "simple-looking" and advertised as both an emoji mathematics problem and an algebra fruit puzzle. Both YouTube videos explained the controversy surrounding the problem, in particular, that it was first posted to Facebook, where it confused over two million people. Notably, the answer to the problem was given at the end of each video.

The comments of 1,046 YouTube users were examined (107 from the first video, and 939 from the second video). All comments were retrieved by the researcher by visiting each YouTube page and scrolling down until there were no remaining posts. Necessarily, this process was conducted over the same time period so that the posts appeared in the same order and could be tracked. Only original posts were studied; replies were only considered if the author of the original post engaged in discourse with other users. It was not possible to obtain any demographic information regarding each YouTube user.

The research followed a qualitative approach (Creswell, 2015) characterized by finding meaning through the subjective interpretation of participants' discourse. The phenomenon to be studied was the indicative nature of discourse to reveal a mathematical mindset and mathe-

Figure 1

Viral Mathematics Problem



Note. Talwalkar, P. (2016). Viral Facebook math problem stumping the internet. (https://mindyourdecisions.com/blog/2016/02/18/viral-facebook-math-problem-stumping-the-internet-answer-to-coconut-plus-apple-plus-banana/)

matical identity. The aim of the qualitative analysis was not to determine the number of YouTube users with the right answer but, rather, to investigate their discourse to identify the mathematical mindset and mathematical identity of each user.

Qualitative analysis began with coding strategies derived from Grounded Theory (Glaser & Strauss, 1967). Open coding (Boeije, 2010) was done mostly at the beginning of the data analysis. During this process, the researcher began to divide the posted comments into groups to form preliminary categories. The enumerated characterizations of these codes were then augmented during the axial coding process (Boeije, 2010) to boost the efficiency of the existing codes. Comments were only coded for one theme; however, if a user engaged in more than one comment, the username was tracked, and, in some instances, the initial code was changed.

In determining the quality of comments, underlying themes emerged, such as an apparent eagerness to boast about their intelligence, diminish the credibility of the mathematics problem, admit their faulty logic, denigrate their self-esteem, or voluntarily explain the solution for other users. To that effect, six codes were formed (Table 1).

After the initial open and axial coding process, selective coding (Boeije, 2010) was implemented in conjunction with Discourse Analysis (Waring, 2018) to determine the mathematical mindset and mathematical identity of each user (Table 2). Notably, mindsets can vary by subject (Yeager & Dweck, 2012) and operate in tension with the general mindset. Thus, the YouTube users in the present study were identified as having a mathematics specific mindset rather than a general mindset, as one cannot assume their general implicit theory of intelligence through the scope of a mathematical lens. Mathematical mindset was determined by examining written language indicators relative to attributions, motivational goals, response to failure, defensive processing, and normative comparisons. In line with an entity theory in mathematics, the fixed mathematical mindset is linked with ability attributions, performance goals, the helpless response to failure, passive and active defensive processing, and normative comparisons. Thus, to identify a social media user as having a fixed mathematical mindset, the researcher looked for indicators in their discourse that suggested the users (1) viewed efficacy as a measure of intelligence, (2) emphasized speed over effort, and (3) criticized the problem, such as devaluing or debunking it, to preserve their perceived rank.

In contrast, the growth mathematical mindset, aligned with an incremental theory in mathematics, is associated with effort attributions, learning goals, and the mastery-oriented response to failure. To identify a social media user as having a growth mathematical mindset, the researcher looked for indicators in their written discourse suggesting they (1) viewed efficacy as distinct from intellectual capacity, (2) sought positive interpretations of their failure, (3) valued effort over speed, and (4) were disinterested in their perceived rank.

Finally, the social interaction on the YouTube page allowed each participant an opportunity to reveal their mathematical identity via the self-image they wished to convey to their audience (Markus & Warf, 1987). The mathematical identity examined was interactional (Waring, 2018); therefore, mathematical identity was determined by the positioning acts (Davies & Harré, 1990) evident in the written discourse of each user. The type of communication studied was one-sided; thus, only first-order positional actions were considered. Six positions emerged from the analysis of discourse: (1) a position of superiority; (2) a position of authority/power; (3) a position of spectator; (4) a position of inferiority; (5) a

Table 1

Coded Comments and their Characterizations Determined During the Open and Axial Coding Process

Coded Comment	Characterization
This is easy	• Emphasis on the short amount of time it took to solve the problem • Emphasis on age • Boasts about own intellectual ability • Disparages people who get the problem wrong
This is not fair	• Disagrees with the presented solution • Devalues the problem
I was wrong	• Willingly admitted they were wrong
I am not smart	• Denigrates self for getting the wrong answer
Let me explain my reasoning	• Provides instruction for other people in a non-disparaging way
Other	• Comments that did not resemble other categories and could not be consolidated into a category of their own • Most often, single number answers to the mathematics problem

Table 2

Mathematical Mindsets and Identities Determined During the Selective Coding Process

Coded Comment	Characterization
Mathematical Mindset: Determined by examining written language indicators relative to attributions, motivational goals, response to failure, defensive processing, and normative comparisons	**Fixed:** • Viewed efficacy as a measure of intelligence • Emphasized speed over effort • Scrutinized the problem, such as devaluing or debunking it, to preserve their perceived rank **Growth:** • Viewed efficacy as distinct from intellectual capacity • Sought positive interpretations of their failure • Valued effort over speed • Were disinterested in their perceived rank
Mathematical Identity: Determined by written language indicators relative to positioning acts	**Position of Superiority:** • Asserted their elevated proficiency in mathematics and desired to maintain their high standing **Position of Authority/Power:** • Asserted their superior proficiency in mathematics while simultaneously executing their authority to exert control over the narrative **Position of Spectator:** • Neutral bystanders to a mathematical debate **Position of Inferiority:** • Asserted their low normative comparison to others and desired to maintain it **Position of Instructor/Solidarity:** • Exhibited both an intent to encourage learning in other users and also solidarity in their understanding of how others had failed **Position of Relative Indifference:** • Disinterested in engaging further in discourse

position of instructor/solidarity; and (6) a position of relative indifference. The emergent themes of positional actions found in the present study were like those described in Bishop's (2012) study of mathematical identities in the classroom.

Analysis

This Is Easy

This discourse exhibited an investment in performance with a focus on speed and age. Speed was emphasized by users explicitly writing their time or using words to delineate their efficiency: "I found out the second I saw it." A link between age and mental prowess was emphasized by users indicating their grade level in school or writing comments such as "Got it right on the first try, and I'm 11."

Additionally, these users were eager to boast about their intellectual ability, writing comments such as, "Honestly, that was easy. I took the gifted test, and things like that were all over the place," and "It's really very simple for me to solve math problems." They also disparaged others who either got the problem wrong or were too baffled to find a solution. For example:

"Honey, I did this in year 1."
"2 million people are unable to answer the question. What dummies they are! Isn't it so simple?"
"This is a toddler's math problem."
"The sad thing is, someone thought it was 7."

One user even denigrated the person that posted the problem: "You just need basic arithmetic to solve it, the person who posted it must be uneducated."

Ultimately, these users were identified as having a fixed mathematical mindset: they valued speed over effort, equated efficacy to intelligence, and cared about their normative comparison. Furthermore, their discourse was indicative of a mathematical identity dependent on their position of superiority: it was evident that they desired to assert their elevated proficiency in mathematics and maintain their high standing. Notably, their role in the narrative assigned an inferior status to the other users.

This Is Not Fair

These users disagreed with the presented solution and devalued the problem. The discourse from these comments revealed defensive processing that impacted the users' ability to process new information, namely, that the problem was not algebraic. They were guarded, oversensitive, and contentious in their inability to accept failure. They engaged in intensified scrutiny to debunk or devalue the mathematics problem itself. Some were polite (e.g., "I'm afraid that you have a mistake in there") while others were blunt (e.g., "You are wrong"). Some went so far as to justify their "non-agreement":

> "I disagree since there is no '+' between the individual bananas and coconut halves adding them is not mathematically correct, you should multiply them instead of adding them, giving a final answer of 14.24264069."

> "At 2:06 you call the picture difference half a coconut ... but by the PICTURE they are not equal sizes … so we are splitting hairs in non-agreement. So depending on how you interpret the 'pictures' will adjust your answer. It boils down to doing the simple algebra properly and consistently. If you decide to be picture accurate though then you should consider using 2/3 for the last coconut picture yes?"

Whereas others exposed it as a popularity-generating scam: "These are designed to purposefully trick people to argue the answer, and create comments to buff popularity." Some even accused it as being a mostly observational problem (e.g., "1% maths and 99% observation"), denouncing it as a trick (e.g., "Fun vid but I lost interest when the 'trick' part came up") or an optical illusion intent on "pure deception." They even scrutinized the quality of the drawings:

> "It was clearly drawn poorly on purpose to cause problems."

> "That coconut looks more like 2/3 than 1/2."

> "This is IKEA's view on math problems making something really simple more difficult just because they [want] to draw pretty pictures."

There was also an abundance of sarcasm, "Maybe you need to count each pixel of the drawn icons separately," and insolence, "This is why we use letter variables instead of pictograph variables." Additionally, many of these comments were aggressive in their delivery, using expletives or all capital letters. Finally, some users employed more complex vocabulary and mathematics to assert their dominance over the correctness of the solution:

> "There's only ONE APPLE in the image representing a value of TEN. Thereby you cannot clearly establish a consistent rule that the images represent real rational numbers that can simply be counted by observing the image, only that there is a specific value as defined by a specific image. Inconsistent rules of variable declaration yields a [expletive] math problem."

Ultimately, these users were identified as having a fixed mathematical mindset: they engaged in defensive discourse and demonstrated a maladaptive response to failure. Furthermore, their discourse was indicative of a mathematical identity dependent on a position of authority. Their comments enforced their position of power by asserting their superior proficiency in mathematics while simultaneously executing their authority to control the narrative. They governed over the solution to the problem in an endeavor to subjugate those who disagreed with them.

I Was Wrong

These users were willing to admit that they, and not the problem, were wrong. Most pointed out the component of the problem they failed to grasp, namely that the quantity of fruit was different:

> "Oh wow, never realized that the amount of fruit varied."

> "I noticed the coconut twist but didn't notice that there was one banana."

Some enjoyed being wrong: "Totally got me. That was fun!" While others were appreciative: "Yeah, I thought the answer was 16 too. I saw this puzzle on a social network, but because it was so easy, I didn't even look at the solution. Now I see things I never noticed before."

Ultimately, these users were identified as having a growth mathematical mindset: they were confident enough in their mathematical ability to the extent that this single mathematical problem did not threaten their intelligence, behavior characteristic of the mastery-oriented response to failure. Furthermore, their discourse was indicative of a mathematical identity comfortable with the position of spectator; these users positioned themselves as bystanders to a grand mathematical debate. They played a neutral role in the narrative, neither asserting themselves as above nor below another user.

I Am Not Smart

These users not only willingly admitted they were wrong but were self-denigrating in the process, depicting a clear loss of self-worth. In addition to lamenting their low intellectual ability, "Why am I so dumb?", they showcased their arithmetic errors in a disparaging tone: "lol I thought 18-10 was 9, so smart." One particular user volunteered two different answers in two different comments and surrendered in a third comment: "Well screw that." Another user went so far as to explain their reasoning in a relatively lengthy post, only to conclude with "I'm gonna get this wrong anyway."

Ultimately, these users were identified as having a fixed mathematical mindset: their self-identification as "dumb" suggests their subscription to the belief that performance is indicative of intelligence. Furthermore, their discourse was emblematic of a mathematical identity dependent on a position of inferiority. These users lacked faith in their mathematical skills, demonstrating discomfort in mathematical socialization and suggesting an abundance of non-mathematical identities. Not only did they assert their low normative comparison to others, but they desired to maintain it, thereby enforcing the superior position of others.

Let Me Explain My Reasoning

These users offered insight to the problem in a markedly non-disparaging way:

> "It is a really simple problem; however, most people did not know that the final answer had to consider the change in quantity of each fruit."

> "The problem people have is they keep changing it to variables. It is pictures of fruit, not letters representing numbers."

Some even explained the solution using real-life scenarios:

> "You go to a shop and see packs of bananas at a discount. 1 pack = 1 euro. You notice that a few of the packs contain just 3 bananas while most packs contain 4. Would you buy the 3-pack??? My point is: we can never afford to dismiss the importance of attention to detail."

They even demonstrated positive growth interpretations from past failures: "I have learned to look a little closer in these things."

Ultimately, these users were identified as having a growth mathematical mindset: they made effort attributions in their constructive criticism of other users' approach to solve the problem. Furthermore, their discourse indicated a mathematical identity emblematic of instructor and solidarity with others; they exhibited both an intent to encourage learning in other users and solidarity in their understanding of how others had failed. Distinct from a position of authority in which the desire was to exert power and control over others, these users expressed a desire to rectify others' mistakes.

Other

All other comments were categorized as "other." Most of these comments consisted of single-number solutions to the mathematics problem. These users demonstrated a clear lack of desire to engage in discourse with others. Due to the ambiguity of motive and lack of sufficient verbiage, it is not possible to determine the mathematical mindset of these users. With that being said, their disinterest is indicative of a mathematical identity dependent on a position of relative indifference.

Results

Of the 1046 comments, the following mathematical identities were revealed through discourse: 170 (16.3%) wrote from a position of superiority; 135 (12.9%) from a position of authority/power; 41 (3.9%) from a position of spectator; 7 (0.7%) from a position of inferiority; 34 (3.3%) from a position of instructor/solidarity; and 659 (63%) from a position of indifference. Additionally, 312 (30%) used discourse suggestive of the fixed mathematical mindset, whereas only 75 (7.2%) of comments were indicative of the growth mathematical mindset.

Table 3
Results

Coded Comment	Associated Mathematical Mindset	Associated Mathematical Identity	Percentage
This is easy	Fixed	Position of Superiority	16.3
This is not fair	Fixed	Position of Authority/Power	12.9
I was wrong	Growth	Position of Spectator	3.9
I am not smart	Fixed	Position of Inferiority	0.7
Let me explain my reasoning	Growth	Position of Instructor/Solidarity	3.3
Other	NA	Position of Relative Indifference	63.0

Discussion

Social media discourse is presently understudied. Extant studies have demonstrated the importance of fostering productive mathematical mindsets and mathematical identities and the integral role that discourse (e.g., classroom, parent to child) plays in their development and progression; however, social media discourse is vastly different from most conventional forms. First, mathematics problems on social media generate controversy. Their portrayal as puzzles only geniuses can solve naturally incites competition. Second, the absence of an answer, or even a collective dismissal of the perceived answer, leads to heated disputes. In fact, authority on social media is sometimes denigrated as opinion. Third, the unfiltered discourse surrounding these posts encourages an unbridled comment culture exemplified by the uninhibited and audacious criticism of others. Fourth, social media discourse is primarily written, limiting users to modern written language indicators of expression. Finally, social media generates a larger, more diverse community than that typically studied. It allows for a unique forum of mathematical discourse that intensifies as the post grows in popularity. Therefore, it is important to examine how social media discourse contributes to mathematical mindsets and mathematical identities.

This study found discourse in social media to indicate both mathematical mindset and mathematical identity; furthermore, mathematical mindset and mathematical identity were linked. The fixed mathematical mindset corresponded to mathematical identities that positioned the user as superior, inferior, or authoritative. This is unsurprising, as the interest each of these users had in ranking their mathematical ability and asserting their relative comparison to others is typical of ability attributions and performance goals. In contrast, the growth mathematical mindset corresponded to those mathematical identities that positioned the user as spectator or instructor/solidarity. Notably, these users made effort attributions and showed complete disinterest in their comparison to others, suggesting their mathematical identities were more robust because they were unthreatened by performance indicators.

Social media can inspire confidence and engender positive change; however, it is necessary to transform harmful notions of efficacy in mathematics and false narratives of what it means to be a mathematician. Arguably, those users that engaged in the most detrimental discourse were those whose intellectual capacity and normative comparison were threatened by their failure. Positional acts are reciprocal; therefore, these users played supportive roles in developing the mathematical identities of others. It is only by understanding the integral role that mathematics socialization in various arenas has in developing mathematical mindsets and mathematical identities that we can enhance mathematical learning and encourage mathematical success.

Future studies should determine further the extent to which mathematical mindsets and mathematical identities are related through positional actions in social media discourse and if the same positioning acts are linked consistently with the same mathematical mindsets. Future studies should also explore how mathematical mindsets and mathematical identities are expressed through positional actions of discourse on social media platforms other than YouTube. Are certain mindsets and identities more prevalent on certain sites? Does the language used by users change as they switch between social media applications? How does student discourse in the classroom relate to student discourse on the Internet, and which indicates their true mathematical mindset and identity?

Additionally, it is important to understand that mindset and identity are multidimensional and should be examined on a spectrum. In fact, the development of these two constructs is continuous and dynamic. Therefore, interventions, such as those that promote healthier mindsets and identities, can embolden learners to reach higher levels of mathematical efficacy. With this knowledge, educators can better equip themselves, and their students, with those speech patterns that promote the mathematical growth mindset and positive mathematical identities. Furthermore, they should better prepare their students to be resilient when engaging in mathematics discourse on social media. Finally, they should be more cognizant of the discourse being used outside the classroom and its effects inside the classroom.

A possible limitation to this study is the lack of detailed analysis of the "other" category, which made up for 63% of the comments. It is difficult to ascertain the motive behind single-word discourse. Perhaps these users were confident in their mathematical abilities to solve the problem with no elaboration. Or maybe they skipped to the end of the video and copied the answer, thereby posting their solution to convince others that they solved the problem. Alternatively, maybe they simply did not care, or maybe they cared just enough to let people know they were "smart." Regardless, their desire to post yet not fully contribute to the discourse is similar to the mathematical identity emblematic of spectator and should be studied further.

Another possible limitation of this study is the subjective interpretation of the coding process. The researcher ensured the validity of the coding process via close reference to the tables of characterizations. However, without the context of tone from spoken language, nonverbal cues, or further questioning by the researcher, it is possible that comments could have been attributed to different coded themes. Future studies should be conducted which include inter-rater reliability. Additionally, in cases where comments may align with more than one coded theme, future studies should incorporate coding comments to more than one theme.

Social media use is on the rise, and its growth has sparked an evolution of, and dependence on, written discourse. Unfiltered and widely disseminated, it is important to increase our understanding of the impact of social media posts. Already, positive and negative health outcomes have been reported from social media use. Thus, it is increasingly crucial that educators recognize the effect that social media interactions have on their students. Ultimately, this unique form of discourse can be used as a conduit for mathematics success through its relation to mathematical mindsets and mathematical identities.

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