Arguing about Synthetic Biology in 140 Characters or Less: Affordances of Microblogging for High School Students Discussions of Socio-Scientific Issues

Mia S. Shaw, Justice T. Walker, and Yasmin B. Kafai
mshaw12@gse.upenn.edu, justicew@gse.upenn.edu, kafai@upenn.edu
University of Pennsylvania

Abstract: As synthetic biology becomes more prevalent, there is a call to critically and publicly evaluate the benefits and risks of such technologies. Microblogs like Twitter have the potential for engaging citizens in civic discourse about such issues but also pose challenges due to partisan behaviors and length limitations. Given the saliency of social media in young people's lives, we examined in an exploratory study whether integrating a 140-character limit within an audience response system supported high school students' argumentation about socioscientific issues during a synthetic biology workshop. After analyzing students' anonymous online responses, worksheets, and observations, we found that students generated diverse evaluative claims as well as used argument-based rationales and weighed counter arguments when assessing their peers' claims. In our discussion, we address the affordances and constraints of microblogging in supporting students' argumentation of socioscientific issues about synthetic biology.

Introduction

Biotechnologies such as synthetic biology have increasingly moved out of research labs and are now more prevalent in our everyday lives and in industries that impact medical, environmental and textile industries. Understood as an engineering discipline, synthetic biology builds complex biological systems from standard, interchangeable biological parts (Cheng & Lu, 2012). In other words, synthetic biology involves the manipulation and design of organisms and/or their outputs. Given the myriad impacts synthetic biology has on society and the environment, a variety of stakeholders including experts, policymakers, and citizens have made evaluating the potential benefits and risks of these applications more salient (Gutmann, 2011). Within a similar vein, there is a call for science education to provide opportunities for students to engage in argumentation around claims developing scientific fields assert in order to simulate the discursive practices observed within scientific communities and in the world at-large (Driver, Newton, & Osborne, 2000). As synthetic biology technologies emerge in K-12 education, students will need to be able to engage in argumentation as future decision-makers and citizens. To this end, they will need to also consider the potential benefits and risks of these emergent technologies and their impact on humans, nonhumans, and the environment.

Microblogs—online platforms where users share and respond to brief 140-200-character messages—and other social media have influenced public awareness about science-related matters and their risks (Auer, Zhang, & Lee, 2014). Even though scientists have criticized using microblogs (e.g., Twitter) for communicating with the public (Shäfer, 2012), these platforms afford discourse wherein individuals witness and participate in diverse conversations they otherwise may not have before (Yardi & boyd, 2010). As Twitter use among young people becomes more and more prominent (Greenhow & Gleason, 2012), research has pointed to the potential for microblogs to serve as platforms for socioscientific (SSI) argumentation skill development among students (Greenhow, Gibbons, & Menzer, 2015). A distinguishing feature of microblogs is that as messages (e.g. "tweets" on Twitter) from different individuals aggregate, their collective whole can form a coherent text where narratives emerge (Murphy, 2013). Considering that wording choices on microblogs can shape how readers process and share information, there exists an opportunity to explore how microblogs promote (or inhibit) science-based discourse (Brossard, 2013). Furthermore, given the character limitation of microblogs, it is important to consider whether or not argumentation of complex SSIs can take place on such a constrained setting.

In this exploratory study, we examine the various ways high school students in a synthetic biology-based workshop discuss SSIs surrounding the field's applications within a microblogging context. In a weeklong summer science workshop, students genetically transformed yeast cells to produce beta-carotene and used this new genetically-modified yeast to produce vitamin-enriched cakes (hereafter, referred to as Biocakes). Following, we facilitated a class-wide discussion about three different synthetic biology applications in the food, medicine, and textiles industries using Mentimeter, a free and existing commercial audience response system

(ARS) that polled and displayed students' anonymous responses. Due to the 140-character limitation on Mentimeter responses, students critically examined these synthetic biology applications in ways that mimicked microblog discourse. We were interested in examining the following research questions: How do students respond to specific synthetic biology applications when limited to 140 characters in a microblog environment? How do students respond to peer's perspectives toward synthetic biology that were formed within such a constrained online setting?

Background

Socioscientific argumentation in science education

The Presidential Commission for the Study of Bioethical Issues recently released its first report calling for experts and policy makers to actively engage in public dialogue about the benefits and risks of synthetic biology in order for citizens to understand these effects on their fellow humans, nonhumans, and the environment as well as to share perspectives about the burgeoning field (Gutmann, 2011). As scientific knowledge is constructed by developing fields like synthetic biology, dispute and controversy emerge, so scientists engage in practices such as argumentation to resolve controversies and to reaffirm valid scientific claims. According to Driver, Newton, and Osborne (2000), new scientific knowledge does not become public knowledge until it has been vetted by the scientific community, and argument plays a crucial role in the practice of critical, public scrutiny. Similarly, the goals of science education are for students to develop the ability to evaluate the aims and results of those who produce scientific knowledge (Patronis, Potari, & Spiliotopoulous, 1999; Yoon, 2008a). Therefore, if science education is introducing students to claims produced by developing scientific fields, it should provide students opportunities to engage in the real-world argumentation practices carried out by scientists (Driver, Newton, and Osborne, 2000).

However, challenges associated with engaging students with contemporary SSIs have stemmed from the depiction of science as an uncontested and unproblematic body of knowledge that is free from critique (Driver, Leach, Millar, & Scott, 1996; Yoon, 2008b). Furthermore, while there have been curricular interventions that have improved students' abilities to evaluate SSIs, many have involved students interacting with texts and problem scenarios or their teachers (Sadler, 2004; Yoon, 2008b)—as opposed to experiencing these technologies first-hand. Incorporating synthetic biology into science education represents a paradigmatic shift from traditional science instruction. Instead of receiving scientific knowledge about bacteria or genetic engineering from an instructor, students genetically modify organisms and experience the field first-hand. As synthetic biology technologies move from university and corporate labs into K-12 education (Kafai et al., 2017), students will need to consider the benefits and risks of such biotechnologies, especially as they actively participate in a cutting-edge field that continues to evolve. In addition to providing hands-on learning opportunities, promoting discourse in which students share their ideas, negotiate multiple perspectives and claims, and evaluate new ideas enriches their learning (Yoon, 2008b). Given that students will participate in design through synthetic biology and engage with claims about this advancing field, classroom activities supporting their civic discourse through argumentation are much needed areas of education research.

Microblogging, discourse and educational uses

Microblogs like Twitter are primarily used for everydayconversations, sharing information, and reporting current news (Java, Song, Finin, & Tseng, 2007). Due to the ability of posts to achieve high levels of interactivity and virality without geographical constraints, microblogs serve as significant platforms for various forms of communication, including political discourse (Colleoni, Rozza, & Arvidsson, 2014). However, the nature of such discourse on Twitter has been found to be highly partisan and worsening, necessitating a need to understand the social and technological dynamics central to this issue (Conover, Ratkiewicz, Francisco, Gonçalves, Flammini, & Menczer, 2011). Furthermore, even though Twitter exposes individuals to multiple, diverse perspectives, as a medium it may be insufficient for rational discourse and debate, as users tend to affiliate with views similar to their own (Yardi & boyd, 2010; Colleoni, Rozza, & Arvidsson, 2014). Therefore, there is a critical need to mitigate the limitations of discourse found in microblogs; one of the ways to do so is by examining the ways in which individuals engage in discourse through argument when microblogging about synthetic biology.

In educational contexts, microblogging can promote collaborative learning, encourage real-time reflective thinking, and increase student participation and engagement (Gao, Luo, & Zhang, 2012). When student microblogging occurred concurrently with classwide discussion at the college level, microblogging afforded new opportunities for discourse (Elavsky, Mislan, & Elavsky, 2011). However, the character limitation can impose constraints on students' critical thinking and self-reflection (Kassens-Noor, 2012). This limitation

can also affect the tone of the post, which can alter how readers perceive the post's content. Given that readers' interpretations of the potential risks of an emerging technology can be affected by a post's tone (Brossard & Scheufele, 2013), students need to be prepared to critically examine potential online claims about emerging technologies like synthetic biology by developing their skills in argumentation. While social networking sites have provided informal opportunities for students to engage in argument about SSIs (Greenhow, Gibbons, & Menzer, 2015), less research has attended to understanding how students engage in argument about synthetic biology on microblogging platforms.

In this study, we utilized an existing, commercial ARS called Mentimeter within our synthetic biology-based workshop that mimics the microblogging features of Twitter to support students' civic discourse through argumentation. Similar to Twitter, Mentimeter constrains responses to 140 characters. However, Mentimeter responses are anonymized and users are unable to interact with each other's posts by @-ing or retweeting. Students were responsible for evaluating multiple, anonymous perspectives and claims from their peers about specific synthetic biology applications. By facilitating a face-to-face discussion about these perspectives, we scaffold student engagement in the discursive practices of argumentation. Given that the discursive practices found in social media can inform students' collaborative discourse (Greenhow, Robelia, & Hughes, 2009), we examine how students form and evaluate claims about synthetic biology in a way that is relevant to their online communication.

Methods

Participants, context, and workshop

The SSI argumentation activity took place on the second day of a five-day, summer workshop that was part of a STEM program at a local science museum. The workshop participants included ten high school students who self-selected to participate in this workshop; however, nine students participated in this exploratory SSI workshop activity. Participants included five boys and four girls. The first two authors were both researchers and facilitators of the workshop, and both have had previously implemented and researched synthetic biology workshops with high school students (Kafai et al., 2017; Walker, Shaw, Kafai, & Lui, 2018).

The objective of the workshop was for participants to learn about and engage with synthetic biology. The workshop consisted of four main parts: 1) a wet lab where participants genetically transformed yeast, 2) mold design where participants had two opportunities to design molds for their cakes using silicone and various shapes, 3) recipe design where participants had two opportunities to bake their vitamin-enriched cakes using their own recipes, and 4) a pitch where participants presented their cakes to a panel of biologists and science educators. In addition to the laboratory and design activities, participants took part in an SSI argumentation activity where they discussed three different synthetic biology applications and the associated impact on humans, nonhumans, and the environment. The goal of the activity was to create an environment for students to share and evaluate multiple perspectives and claims about the applications. In particular, participants engaged in discourse about these applications using Mentimeter. A snapshot of the interface and responses are displayed in Figure 1.

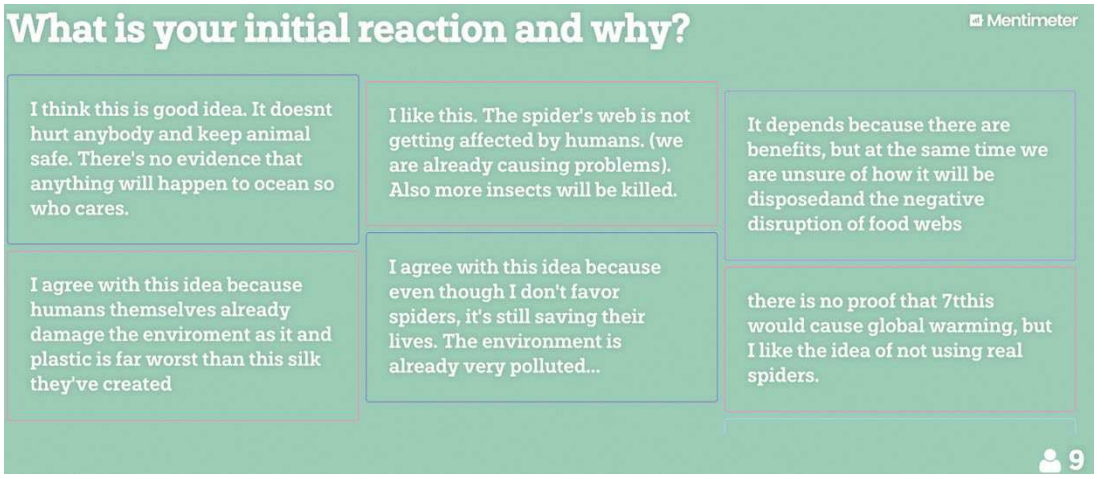

Figure 1. Screenshot of Mentimeter page displaying participant responses.

The entire microblogging activity took place for approximately 50 minutes. Participants read prompts explaining the benefits and risks of Golden Rice, CAR T-cell therapy, and Adidas Biofabric (see Table 1 for descriptions of each synthetic biology application and excerpts from the prompts). Using their individual computers, participants anonymously shared their initial reactions to each of the synthetic biology applications, which were immediately displayed for the entire class on the front screen to generate discussion. After reading everyone's reactions, students reflected individually in response to two prompts: (1) After seeing the results, what do you find most interesting? Why? and (2) Find an argument that is most similar to yours and provide a possible counterargument. Lastly, participants engaged in a class-wide, face-to-face discussion based on their reflections.

Table 1: Synthetic biology application

Application (type)	Description	Prompt excerpts
Golden Rice (plant microbial)	Rice is genetically-engineered to contain high levels of the vitamin-A-precursor, beta-carotene	*"...Although Golden Rice has been available for some time now, it is unclear whether it has had the lasting benefits everyone expected. This is largely because Golden Rice tends to be more expensive to make than traditional rice. ..."*
CAR T-cell therapy (human)	Newly developed cancer treatment that uses parts of the HIV virus to genetically modify white blood cells to recognize and destroy cancer cells	*"...Many experts in the field are calling this genetic engineering approach a new "pillar" of therapy because it does not involve rigorous chemotherapies or invasive surgeries...."*
Adidas Biofabric (microbial)	Shoes designed using synthetic spider silk	*"...*While this approach seems to be entirely beneficial, some critics have suggested that this will generate even more waste into the globe's oceans, which are already plagued with record levels of plastic pollution..."

Data collection and analysis

Data collected for this study included the participants' anonymized Mentimeter responses, individual worksheets participants used to reflect on peer responses, and video observations and fieldnotes. The first author began analysis by watching an excerpt of the video data of participant discussion of Golden Rice in order to observe how participants engaged in argumentation using Mentimeter. Through grounded analysis (Charmaz, 2002), the author noted and grouped participants' discussion quotes in order to develop emergent, preliminary codes representing participants' discursive practices when recording their initial evaluations about Golden Rice and critically examining their peers' evaluations. These codes were evaluated and clarified through memoing and feedback from the second author. After we applied the codes to the remainder of the video observations and participant Mentimeter and worksheet responses, new themes emerged across the three data points. However, given that the focus of this is on the affordances of microblogging for engaging in argumentation, we decided to focus the remainder of the analysis on the Mentimeter and worksheet responses. Both authors revised the codes until consensus was reached and applied focused coding to the Mentimeter and worksheet responses by using the most significant and frequent codes. There were two categories of codes: among the initial Mentimeter responses, codes focused on participants' attitudes toward each of the applications (e.g., not accept, balanced, accept, and unclear), and among the worksheet responses, codes focused on how participants evaluated peer claims (e.g. consensus, critiquing argument, justifying argument, etc.). Lastly, the authors drew relationships between these codes into themes that reflected how participant argumentation about synthetic biology was supported through the use of Mentimeter.

Findings

Finding 1: Participants' evaluative claims depending on application type include a myriad of considerations

We begin by reporting on participants' anonymous Mentimeter responses to three synthetic biology-based applications. We found that when participants were asked to describe their initial reactions toward the three applications using Mentimeter, they not only made evaluative claims but when their responses were aggregated and displayed to the whole class, two main narratives emerged. First, the type of application (e.g., microbial, human, and plant) influenced whether or not participants' claims expressed support, lack of support, or a balanced perspective regarding the applications. Overall, the majority of participants found exclusively microbial applications acceptable (6 out of 8) while the majority of participants found human (6 out of 8) and plant applications (4 out of 8) unacceptable (see Table 2). Participants also made claims that were balanced, that is, neutral toward a microbial application overall. The following anonymous Mentimeter response reflects this as the participant noted, "it depends because there are benefits, but at the same time we are unsure of how it will be disposed and the negative disruption of food webs." In making their claim, this participant did not express support or lack of support for Adidas Biofabric; instead, the student acknowledged the application's benefits and risks. However, two participant responses were unclear but for disparate reasons. When evaluating Adidas Biofabric, it was challenging to determine one participant's attitude toward the application as they explained, "there is no proof that 7tthis would cause global warming, but I like the idea of not using real spiders." This participant's use of the conjunction "but" makes it difficult to determine the tone of their claim. In addition, even though participants were tasked with writing one reaction, there was one extra anonymous response displayed that stated, "There is no proof that this will happen." It is unclear what "this" the participant was referring to or if this response was intended as a continuation for their previous claim. These unclear examples allude to a potentially negative influence that a 140-character limitation can have on the tone of an argument, as well as how extraneous posts can distract from the coherent narratives found within a microblog's feed.

Table 2: Range of attitudes found participants' evaluative claims

Application Type	Support (N)	Not Support (N)	Balanced (N)	Unclear (N)	Total (N)
Microbial - Adidas Biofabric	6	-	1	2	9
Plant - Golden Rice	2	4	2	-	8
Human - CAR T-Cell	1	6	1	-	8

The second narrative illustrates that in making their evaluative claims, participants made a wide range of considerations regarding the impacts of the synthetic biology application. When making their claims about Adidas Biofabric, participants frequently considered the specific impact of the microbial application on multiple contexts: humans, non-humans, and/or the environment. This is exampled in one anonymous Mentimeter response as the participant explained, "I think this is good idea. It doesn't hurt anybody and keep animal safe. There's no evidence that anything will happen to ocean so who cares." They not only expressed support for the Adidas Biofabric but considered the impact of the microbial application on humans ("anybody"), non-humans ("animal"), and the environment ("ocean"). This was the only response that considered the impact of the application on all three contexts. When making their claims about Golden Rice and CAR T-cell therapy, participants considered the impact of the plant-microbial and human applications in broad terms and/or to humans in particular. This point was illustrated when an anonymous Mentimeter response disapproved of CAR T-cell therapy as the participant noted, "NO! It could easily attack other tissues and foreign thing that could be good for you. It could be very dangerous if it gets out of control." This participant cautioned that the potential impact on humans makes this application of synthetic biology unacceptable. However, another participant made broad considerations when evaluating Golden Rice, declaring, "My initial reaction was rather between the two arguments. There is the chance of both negative and positive outcomes, so anything can happen." Even though their claim was of a balanced perspective, it lacks specific considerations of Golden Rice's impact, making it a challenge to determine whether or not this participant fully understood the application's benefits and risks. Finally, participants also based their considerations on benefits, costs, and usefulness of the application. In

response to Golden Rice, an anonymous Mentimeter response asserted, "in between. It is very expensive to make and it could be harder to harvest. However most communities that are Vitiam A deficient could use." Here, the participant explained that costs and usefulness are central considerations in their overall claim, which is balanced. These findings suggest that microblogging has the potential of supporting students' critical thinking regarding the impacts of synthetic biology applications.

Finding 2: Participants' argument-based rationales evaluate other perspectives.

After displaying all of the participants' 140-character, anonymous Mentimeter responses, participants answered the following question on individual worksheets: "After seeing the results, what do you find most interesting? Why?" We found that when participants read all of their peers' perspectives on Mentimeter, they engaged a claim in terms of whether or not it aligned with their own and evaluated it according to the rationale presented in the claim. Regarding the three synthetic biology applications, participants frequently asserted agreement with a given rationale: microbial applications (4 of 8 responses), plant-microbial applications (4 of 7 responses), and human applications (4 of 8 responses). This was exampled in responses like Natalie's when she explained, "the most interesting reasoning is the one that speaks about the [effects] on the environment but also the potential good things that come out of it. This is because it [exhibits] the potential outcome on both sides." Like several participants, Natalie asserted her agreement with this claim regarding Adidas Biofabric based on the fact that the rationale is balanced and in consideration of two viewpoints. In addition to asserting agreement, argument building was reflected in moments when students indicated they agreed with a given claim and advanced the rationale by asserting additional ideas in support of the given perspective. This was evident in Edward's point when he explained, "I found the 'sold at higher' price one intresting I say this because you can't simply sell something that you aren't at complete assurance of it being harmless." Here, Edward adds to a peer's lack of support towards Golden Rice being sold at higher prices without knowing the benefits by asserting the need for assurance that the application is harmless. The frequent asserting of agreement and argument building alludes to the potential of microblogging in reinforcing participants affiliating with peers who share their views.

Participants also asserted critiques towards given claims and their rationales. When participants considered microbial-based perspectives that were contrary to their own, their evaluations were also rationale-based and included a critique of the opposing perspective. This was illustrated in participant responses like Michael's who explained, "I think the response that says that we should use it because we already damage the environment is interesting. The reasoning is kind of dumb. It's like saying if a car is broke, you should break it some more." Michael pointed out that the rationale to use synthetic biology-based applications on plants despite the potential environmental effects because the environment is already polluted is erroneous and uses an analogy to underscore his point. Even though only two participants critiqued their peers' claims and rationales, this demonstrates the potential of participants being able to critically evaluate claims about synthetic biology they may be exposed to in microblogging platforms.

Instances when participants pointed to a perspective and its rationale as illuminating occurred infrequently. These perspectives reflect times when students found a perspective and rationale different from their own, but interesting nonetheless as Carla noted, "I found the fact that other people mentioning the price was interesting because I personally didn't consider the price." As Carla explained, the rationale advanced by one of her peers was a perspective she had not considered previously but was something she found notable. This supports the potential of microblogs in exposing participants to perspectives and discussions they may not have been witnessed before.

Finding 3: Participants weigh counter arguments in relation to their own

Lastly, when answering the worksheet question: "Find an argument that is most similar to yours and provide a possible COUNTER ARGUMENT," participants were able to develop counter arguments to claims aligned with their own as displayed on Mentimeter. This occurred across synthetic biology-based contexts including microbial applications (3 of 7 responses), plant-microbial applications (4 of 7 responses), and human applications (3 of 7 responses). For instance, when Heather considered her own claim about using synthetic biology on microbes, she noted, "although there are many benefits there is a possibility to hurt food webs which is a major issue." Heather weighed the potential benefits that guided her overall counter argument against the potential impacts the technology could have on the environment. With regard to plants, a similar outcome occurred as illustrated in Leah's point that "golden rice... tastes good and has enough Vitamin A; although, no one knows the impact which could be a bad thing." Here, Leah broadly considered the potential for adverse outcomes when using synthetic biology in plant-based applications.

Similarly, students weighed counterarguments against their own perspectives about human-based synthetic biology applications. This is exampled in Edward's response as he explained, "I'm going to use the

point from earlier. The counter argument could be: you have to give it a chance, because you could say the same thing about most inventions. You don't know the risks but you have to take it." Here, Edward noted that despite the potential harm that could arise from using synthetic biology on human cells—a perspective that aligns with his own—there are risks associated with most technological advances, making this not a unique situation as well as a necessary part of making progress. Participants' ability to construct counter arguments based on their peer's 140-character claims alludes to the potential of considering perspectives they may be exposed to on microblogging platforms that conflict with their own.

Discussion

In this study, we facilitated a discussion about synthetic biology by using an online microblogging platform which, like Twitter, limits responses to 140 characters and by observing how students engage in argument through such constraints. Despite the character limitation, students were able to construct concise yet diverse evaluations of the three different applications based on a range of considerations (impact on humans, environment, and animals and their usefulness). In addition, students were able to form and weigh counterarguments against their own initial arguments. Previous research suggests that Twitter can foster an increased creating and sharing of ideas beyond the classroom due to the automatic tracking of tweets by day and time, supporting continuous participation of users (Kassens-Noor, 2012). Even though Mentimeter lacks this ability to track responses across time, our findings suggest that such platforms can foster combined knowledge *within* the classroom due to participants' ability to examine and draw arguments from multiple peer perspectives. Furthermore, even though Twitter provides identifying information about users, Mentimeter anonymizes users. Given that anonymity can improve discussion participation (Hsi & Hoadley, 1997), its use may have mitigated the social influence effects found on social media, allowing more students' evaluative claims to be drawn upon.

However, considering that most students did not make considerations about the synthetic biology applications simultaneously across humans, nonhumans, and the environment, the 140-character limitation may have constrained their ability to do so. When presenting the scenario for each application, we provided potential impacts of the application on humans, nonhumans, and the environment. Nonetheless, participants' arguments tended to be based on impacts that were either broad or concerning just one or two of the three impacts we provided. Considering that evaluating the impacts across all these categories is a quintessential part of being a steward of humans, nonhumans, and the environment as a whole (Gutmann, 2011), this observation illustrates a potential limitation of microblogging in that 140 characters may have forced participants to focus on a topic without allowing them to express complex thoughts (Junco, Heiberger, & Loken, 2011). In addition, it is interesting that in evaluating their peers' perspectives, the majority of students expressed agreement with their peers' arguments. Given the complexity of the issues surrounding synthetic biology, it is possible students may be drawn to perspectives that are similar to their own, reinforcing an echo chamber (Colleoni, Rozza, & Arvidsson, 2014) of their own bias and solidifying them on these platforms.

While this study was exploratory in nature, it did illuminate some interesting phenomenon that should be explored in further research. An element of SNSs that was not present in our discussion was the ability for students to respond to their peers' perspectives online as well as read each other's response. Given that microblogging can document learning processes in real-time, students themselves could better understand their own and their peers' argumentation process given the proper scaffolds. This documentation of their argumentation could be utilized to highlight the complexity of synthetic biology. This study provides a start to exploring the affordances and constraints of microblogging features such as character limitations in engaging student in argumentation surrounding synthetic biology and other SSIs.

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