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# An empirical analysis of knowledge co-construction in YouTube comments

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ABSTRACT

Internet and social media platforms such as YouTube are an emblem of information on demand, but, their educative value, especially for conceptually rich domains, such as science, remains unclear. Many people perceive YouTube as a good resource for learning about science, yet viewing many of the available videos can be akin to learning through transmission models, which are considered inferior when they are the sole form of instruction. The goal of this study was to examine whether YouTube's embedded feature of posting (post-video) comments could mitigate these limitations, and offer a potential educative added-value by opening opportunities for discussion and deliberation, which have been associated with deeper learning. Focusing on Science as a target domain, we examined 1530 post-video public comments from a corpus of leading science channels. We coded the comments for argumentative and knowledge construction moves, and tested whether particular moves led to higher-level knowledge construction. Our findings reveal that this informal setting reflected comments that went beyond information sharing to argumentative negotiation, reaching a higher level of knowledge construction, and yielding a greater proportion of such comments that have been found in previous studies within formal settings. This study demonstrates that YouTube can offer an informal space for science deliberation and a forum for collaborative interactions that have a potential to support life-long learning. Implications for future research are discussed.

## 1. Introduction

Which platforms can enable individuals to learn through informal interactions when life decisions or work mobility call for new knowledge? The internet and social media are commonly perceived as productive resources for ongoing learning (Duffy, 2008; Hattingh, 2017; Holland, 2019; Manca, 2018; O'Reilly, 2005). Yet, there is little empirical evidence that online interactions yield productive learning of conceptually rich domains such as science (Holland, 2019). In this paper, we take first steps toward providing such empirical evidence by examining whether post-video comments on YouTube reflect precursors to learning. That is, we investigate whether they reflect the markers of productive argumentation and discussion moves that have been identified and associated with learning in formal settings.

This paper responds to the growing interest in informal learning and to calls to explore the social nature of collaborative knowledge

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construction in "real-world, authentic settings beyond classroom and formal educational settings" in rising to the challenge to "bring exciting new theoretical dimensions into our research" (Ludvigsen, Cress, Law, Rosé, & Stahl, 2016, p. 260). We first argue for the need to understand the role of social media in supporting informal learning of conceptually rich domains and present our rationale for focusing on science videos on YouTube. Next, we present an overview of YouTube and its potential educative uses, followed by an analysis of argumentative discourse and knowledge construction in the post-video comments of various high-trending science videos on the site. We conclude with a discussion of the educative value of YouTube and possibilities for future research concerning the role of the internet and social media for life-long informal learning of conceptually rich domains.

### 1.1. *Social media's potential in informal learning of conceptually rich domains*

Today's information society is characterized by the increased importance of information production and consumption in economic strength and growth, as well as by the central role that digitization, computation, and communication play in civic participation (Brennen & Kreiss, 2016). The half-life of knowledge is decreasing while mobility between careers over the adult lifespan is increasing, creating new knowledge and learning needs (Siemens, 2018). Formal education, even at the higher education level, is no longer sufficient to fulfill the life-long learning needs of professional and personal lives (Cerasoli et al., 2018). The emerging inadequacy of formal education alone has raised awareness regarding the need for more opportunities and a better understanding of non-formal and informal learning (Werquin, 2012).

Unlike formal learning in schools or universities, non-formal learning, such as in museums, refers to learning that is organized in some way, follows planned programs, but is usually more loosely defined than the learning that takes place in formal settings, and typically does not award academic credit (Ainsworth & Eaton, 2010; Cameron & Harrison, 2012). Informal learning, the focus of this study, departs from formal and non-formal learning in that it is hardly ever organized or guided by a program or curriculum; rather, it arises from the experiences of daily life, such as through interactions with colleagues at work (Ainsworth & Eaton, 2010; Cameron & Harrison, 2012; Colardyn & Bjornavold, 2004). Based on mounting recognition of its value, employers, governments, and formal educational institutions are granting increasing credence to informal learning (Ainsworth & Eaton, 2010; Becker et al., 2017), while the public is increasingly engaging in informal learning for work and non-work related purposes (Cameron & Harrison, 2012). A large percentage of public informal learning involves the use of computers, the internet, and social media (Cameron & Harrison, 2012).

With the emergence of Web 2.0, platforms such as blogs, wikis, social media and video sharing websites have redefined the mediascape by providing support for user-generated content and user interactions. These environments transform users from 'consumers' or 'audiences' who only watch or read online information, into 'prosumers' – active producers and distributors of new content among online communities of interest (Shifman, 2012; Waldron, 2013). Consequently, the introduction of social networking sites creates potential new opportunities for informal learning (Duffy, 2008; O'Reilly, 2005).

### 1.2. *The internet and social media: deceptive allure or educative environments for informal learning of conceptually rich domains?*

The internet and social media are perceived as promising platforms for informal learning because they are popular, accessible, and host a vast amount of information (Burgess & Green, 2009; Duffy, 2008; Welbourne & Grant, 2015). Yet for conceptually rich domains, this allure may be deceptive. Conceptually rich content is typically presented in a way that reflects transmission models of instruction, which are associated with a surface understanding and inert knowledge (Bransford, Brown, & Cocking, 2000; Hansch et al., 2015; National Academies of Sciences & Medicine, 2018; Schwartz & Hartman, 2007).

Nonetheless, online knowledge-sharing platforms and social media also include opportunities for people to comment on and discuss the posted content, thus providing a chance to engage in argumentation, which is associated with constructive processes and learning (National Academies of Sciences & Medicine, 2018). Notably, the technical features that enable content comments do not guarantee or determine learning (Kozma, 1991; Selwyn, 2016); they merely offer opportunities absent from environments based solely on viewing. Whether these comments and discussions of online educational materials actually include productive discourse and lead to learning remains an open empirical question. This question must be answered in order to understand the educative value of these environments for informal learning of conceptually rich domains. The present study takes a first step toward answering this question using the focal case of science videos on YouTube, examining whether post-video comments reflect markers of productive argumentation as an indication of precursors to viewers' learning processes.

### 1.3. *Informal learning of conceptually rich domains on social media: YouTube as a case example*

YouTube was launched in 2005 to enable any subscriber to create, upload, and share original content ranging from homemade videos to movie scenes. It is not merely the second-most popular platform in the world for broadcasting content (just behind Google.com, Alexa Internet Inc., 2019), but an emblem of the emerging participatory culture, whereby people acquire information on demand that is embedded within social interaction in the form of commenting, seeking, and providing information (Tan, 2013). Interaction with YouTube as a social space allows the discovery of new materials in a self-directed mode, thus satisfying different information-seeking goals. This positions YouTube as a fertile case example for identifying productive platforms, and for understanding processes of informal learning.

YouTube is replete with video tutorials for *procedural* tasks, such as doing your nails or replacing your hard drive; several studies document the learning of such skills using YouTube. In fact, "how to" was one of the most searched-for terms on Google in 2018, and there were 42.1 billion views of online tutorial videos on YouTube that year (Marshall, 2019). We use the term *procedural* to refer to learning that has motor, visual, or auditory components, such as specific troubleshooting of a printer jam (Rodriguez, 2002); laptop memory replacement (Michas & Berry, 2000); handheld device assembly (Watson, Butterfield, Curran, & Craig, 2010); learning of technique-based musical objectives (Kruse & Veblen, 2012; Waldron, 2011, 2013); or medical techniques, i.e., a step-by-step tutorial of how to perform a lumbar puncture procedure (Akgun et al., 2014; Rössler, Lahner, Schebesta, Chiari, & Plöchl, 2012). People are able to develop their procedural motor skills by performing the actions while watching the sequences in motion with actual objects and tools.

Despite evidence supporting the learning of procedural skills on YouTube, it is unclear whether the site can be an effective medium for supporting informal learning of conceptually rich domains. Learning conceptually rich domains is challenging and complex, because it requires learners to forge connections between large networks of information, engage in abstraction, and reason about processes and causality rather than just memorize facts (Bransford, Brown, & Cocking, 2000; National Academies of Sciences, 2018; Van Merriënboer, 2016). To learn conceptually rich domains effectively, most learners need external structures and prompts that encourage them to be explicit about their assumptions, articulate their understandings, confront their interpretations with normative knowledge, and figure out how to make sense of novel explanations – especially ones that conflict with their preconceived ideas (Bransford & Donovan, 2005; National Academies of Sciences, 2018). These are learning behaviors and activities that are usually absent from settings that rely solely on transmission. Simply viewing informative videos may not be sufficient to induce such learning. Therefore, one of the most popular venues may actually be the poorest choice for such goals. This tension and the paucity of empirical research makes YouTube a promising case example for understanding whether and how social media can serve as a platform for the informal learning of conceptually rich domains.

In using YouTube as a focal case, we should note that the use of video on platforms such as YouTube for learning and instruction is broader than the scope we investigate in this paper. For example, the use of YouTube for non-formal or formal learning programs, or the use of interactive video, video annotations, or other video production interventions (e.g., Bull et al., 2008; Snelson, 2018) fall beyond the prism of our analysis. However, findings from the literature on the use of video in learning further motivate the inquiry we undertake in this paper.

Although the combination of auditory and visual channels lend video an advantage over static representations as a medium for instruction (Merkt, Ballmann, Felfeli, & Schwan, 2018), learning from video has both advantages and limitations. Linear video that is akin to a recorded lecture reflects a transmission model of instruction, consequently, it is likely to result in inert knowledge, even if the video is visually and audibly appealing, such as when the video shifts between vibrant speakers and animations that illustrate the content of the speech (Merkt et al., 2018; Palaigeorgiou & Papadopoulou, 2019). Therefore, intentional complementary pedagogical structures and moves are needed in order to reap its benefits (Bell & Bull, 2010). One direction taken in both formal and non-formal environments is the development of interactive video that breaks away from standalone linear video, and instead intersperses actions on and with the video, such as responding to questions, or segmenting labeling and annotating the video in order to encourage reflective 'minds-on' learning (Palaigeorgiou, Papadopoulou, & Kazanidis, 2019).

Posting interactive videos requires intentional design on the part of the content authors and may not be a viable option for all posted videos, especially in the case of person-to-person knowledge sharing. It is likely that a critical mass of transmission-oriented non-interactive videos will remain a mainstay of the online landscape for the foreseeable future. Therefore, understanding whether and how post-video comments can provide educative added value is instrumental to differentiating hype from reality as the public turns to social media for informal learning.

### *1.4. Reliability and accuracy of information on YouTube*

In order for YouTube instructional videos to have an educative value, the information and procedures that appear in them need to be reliable. Although the question of who determines or sanctions knowledge and procedures is equivocal, in this article we define reliability as information that accords with the consensus in leading scientific journals or central professional organizations (Krippendorff, 2008). Numerous studies have documented severe quality deficits in the information provided by videos posted online (Eysenbach, Powell, Kuss, & Sa, 2002; Keelan, Pavri-Garcia, Tomlinson, & Wilson, 2007; Steinberg et al., 2010), stating that some of the videos' information quality "pose[s] a grave threat" (Rössler et al., 2012, p. 657). This threat is heightened by the unlimited ability of users to upload open-ended materials, which can then be further shared. As such, awareness of information accuracy is key in this context (Stadtler & Bromme, 2007). This poses the question, what means are available to YouTube users in evaluating the veracity of the content that is uploaded?

YouTube offers a number of features that can help users evaluate the quality and reliability of the videos' content. These features include various measures to assess popularity (i.e., popularity rankings, number of views), the ability to upload an unlimited number of videos, and to post comments, which may further encourage users' discussions and interactions. Some evidence suggests that these affordances of collective and individual social engagement support information evaluation and sourcing within social media spaces.

For instance, Azer (2012) evaluated YouTube as a medium for learning anatomy and concluded that although only 27% of videos were useful for teaching and learning purposes, the useful videos had a daily viewership on average double than that of non-useful videos (38 vs. 16 views/day, on average). Sood, Sarangi, Pandey, and Murugiah (2011) analyzed 199 videos on kidney stones and found that informative videos received significantly higher views than ones offering misleading content. Pandey, Patni, Singh, Sood, and Singh (2010) evaluated YouTube as a source of information on the H1N1 influenza pandemic, with similar results. They found that 61.5% of videos from their pool offered accurate information about the disease, and that information contributed by the Center for Disease Control (CDC) had the highest viewership share. Duncan, Yarwood-Ross, and Haigh (2013) assessed 100 YouTube channels focusing on clinical skills. They found evidence that viewers recognize quality and express approval through the 'like' button on the

YouTube site. Interestingly, while Kulgemeyer and Peters (2016) did not find a link between quality and YouTube features such as likes, dislikes, and number of views, they did propose another promising measurement for videos quality; namely, the amount of relevant content-related comments. In this sense, user-to-user to content interactions (i.e., sharing, popularity rankings, and comments) creates a collective literacy in information evaluation. Although threats to reliability may be mitigated, it is unlikely that they can be entirely avoided. However, there appear to be enough opportunities to reach reliable information on YouTube to merit an examination of its educative value, for which accuracy may be a necessary but insufficient factor.

### *1.5. Public comments as a vehicle for knowledge construction on YouTube*

Online knowledge sharing is a well-known construct in communication, business, management, and information sciences (John, 2013). Knowledge sharing refers to activities in which individuals make their own internally stored knowledge and/or external knowledge sources that they have at their disposal accessible to others. In the majority of cases, there is no direct reward for making one's knowledge available. Knowledge sharing requires time and effort to assemble and share online and involves letting someone else have something that you have, often without knowing who benefits from this knowledge. In educational contexts, studies have found knowledge-sharing discourse to be a common online practice among students (Fu, van Aalst, & Chan, 2016; Wise, Hausknecht, & Zhao, 2014).

Knoweldge co-construction involves going beyond knowledge sharing. Knowledge co-construction describes processes whereby individuals not only share their knowledge, but engage in collective modification and examination of each other's ideas, which in turn leads to idea improvement; namely, collective knowledge building (Scardamalia, 2002; Scardamalia & Bereiter, 2014). Different individual voices are distinct, but through argumentative deliberation, individuals are able to identify dissonances and adopt differential positions, thereby achieving shared group cognition (Jeong, Cress, Moskaliuk, & Kimmerle, 2017; Stahl, 2006).

Social media, such as WhatsApp, FaceBook, YouTube, and other portals, may promote the transition beyond knowledge sharing to co-construction and informal learning, since they enable users to discuss the shared content. Yet critical evaluation, refinement, or improvement of ideas shared on such sites is not guaranteed (see Henderson, Selwyn, & Aston, 2017; Selwyn, 2009), and insufficient empirical knowledge exists as to whether such processes occur on social media, although this is an area of growing interest (e.g., Tsovaltzi, Greenhow, & Asterhan, 2015).

In an experimental setting that compared learning from reading FaceBook discussions that reflect a disputational discourse (the goal is to convince an apponnet to swithc side) or a delibrartive discourse (here the gaol is to arrive collabortively to a mutaul conclusion), the deliberative condition yielded greater learning (Asterhan & Hever, 2015). This finding suggests that learning can occur through social network site discussions, but that learning hinges on the nature and form of the discussion. Moreover, it is unclear whether learning-supporting discussions occur spontaneously, because the small number of studies available yield mixed results.

Asterhan and Bouton (2017) investigated secondary-school students' interactions with WhatsApp, and found that their communication was mainly characterized by peer-to-peer exchange of information and knowledge sources, and not by in-depth, peer-guided knowledge co-construction. Similarly, Selwyn (2009) explored students' education-related use of Facebook and found that most interactions on a university site's general page were merely social and often even 'anti-intellectual.' In contrast to findings related to formal education, an analysis of public comments in response to articles on a Facebook site concerning specific areas of interest such as climate change showed the use of productive argumentative and co-construction discourse moves (Greenhow, Gibbins, & Menzer, 2015).

Similarly, in research looking at YouTube specifically, Shapiro and Park (2015, 2018) revealed that despite the lack of any facilitators to guide the interaction, argumentative discourse indeed took place in the comments section of various videos. The argumentative public communication was supported by users who posted some scientific evidence and by other subscribers who questioned that evidence by providing counter-claims and citing academic sources. Hence, while Thelwall, Sud, and Vis (2012) showed that YouTube commenters are predominantly male (72.2%) and that less than 0.5% of viewers leave a comment, they still concluded that the site creates genuine debates on controversial issues, which raises the possibility that "YouTube is a significant public space (or even a public sphere, Habermas, 1991) for engaging in debate and exchanging opinions" (p. 627). Thus, YouTube has the technical capacity to host productive debates via comments or video replies.

### *1.6. Science as a focal case of a conceptually rich domain being researched on YouTube*

We chose science as a focal domain, considering for example whether through watching YouTube videos, people can develop an understanding of epidemiological processes or of the implications of Pangea formation. Scientific understanding hinges on many different aspects of our daily lives, and many people seek scientific information online (Brossard, 2013; Segev & Baram-Tsabari, 2012; Tabak, 2016). For example, people might want to understand "why do we laugh when we are tickled?" or "which type of mold is harmful?" (Artz & Wormer, 2011, p. 883). YouTube has been noted as an important resource for finding out about ecological systems in particular (Dylewski, Mikula, Tryjanowski, Morelli, & Yosef, 2017; Füchslin, Schäfer, & Metag, 2019). Recent initiatives, such as the upsurge of citizen science activities, suggest that public engagement with science and the need for developing serendipitous scientific understanding may be a growing trend (Polman & Hope, 2014; Timmis et al., 2019).

Scientific reasoning and understanding involves developing causal models of the ways in which the natural world operates (Mintzes, Wandersee, & Novak, 2000; White, 1993). Although throughout the lifespan people observe the world around them and develop personal theories that explain what they see, these personal theories do not always align with formal scientific models (Glynn & Duit, 1995; Schauble & Glaser, 1990; Zimmerman, 2000). Many natural phenomena involve complex chains of causality and processes that are not visible – such as cellular processes, energy transfer, or changes in population composition over many generations – making it difficult to develop personal or folk explanations about these processes that are consistent with formal scientific models (Kozma, 2003; Tsui & Treagust, 2003; White, 1993). Moreover, once people develop their own alternative theories, it is difficult for them to change these theories and adopt a scientific canon (Asterhan & Schwarz, 2009; diSessa & Minstrell, 1998; Venville & Treagust, 1998). Non-formal science learning, such as the learning that takes place in museums, often positively impacts both attitudes toward science and understanding of scientific concepts (National Research Council, 2009; Schwier & Seaton, 2013; Sommerauer; Müller, 2014). Therefore, such learning can create productive synergy between formal, non-formal and informal science learning. For example, learners who self-reported enriched informal science learning experiences scored higher on a classroom scientific reasoning test than learners who self-reported poor informal science learning experiences (Gerber, Cavallo, & Marek, 2001). The past several decades of science education research suggest that efficacious instruction should focus on attending to learners' prior beliefs, challenging them, and offering convincing alternatives (Bransford & Donovan, 2005; Duschl, 2008; Eylon & Linn, 1988; Gerber et al.,

**Table 1**
YouTube video titles, associated channels and descriptive details for videos analyzed in this study.

| Channel | | Videos that were collected and analyzed | | | | | |
|---|---|---|---|---|---|---|---|
| Channel Title | Channel details | Video Title | Video details | Analysis | Video's Characteristics & Narrative | Is there an invitation for debate? | Comments Narrative & Science related Concepts |
| Kurzgesgat - In a Nutshell | No of videos: 97 No of views: 618248056 No of subscribers: 8763806 | Why Meat is the Best Worst Thing in the World | Length: 8:48 min Created: 2018 Total comments: 66 999 | 412 comments | Informational & Exclamational video. The video concerns how meat production harm the environment and how this harm can be reduced. | The presenter did not explicitly request that viewers post comments. However, below the video, the following written notification appears: "Meat is a complicated issue. But also a delicious one. Let's talk about it." | Definition and distinction of meat diet, vegetarian and vegan diets; effect of nutrition on health and environment; ethical consequences of food choices |
| Science Channel | No of videos: 1943 No of views: 456751813 No of subscribers: 2077861 | Is This Island Moving? What on Earth? | Length: 2:58 min Created: 2018 Total comments: 6657 | 158 comments | Informational & Exclamational video. The video concerns the undersee volcano eruption phenomenon that creates a moving island. | There is no explicit invention for posting comments | Pangea definition, formation and implication; tectonic plates shift; Volcano eruption phenomenon |
| | | Could This Be the Legendary "Magic Bridge" Connecting India And Sri Lanka? | Length: 2:26 min Created: 2018 Total comments: 5923 | 394 comments | Informational & Exclamational video. The video describes geological phenomena of stone structures that connect India and Sri Lanka | There is no explicit invention for posting comments. | Geological evidence, historical and etymology references; credibility epistemological characteristics to establish or disprove an Indian religious legend as a historical event |
| SciShow | No of videos: 1880 No of views: 989477291 No of subscribers: 5621886 | The First Gene-Edited Babies Are Here, Like It or Not | Length: 7:03 Created: 2018 Total comments: 4847 | 264 comments | Informational & Exclamational video. The video elaborates about an illegal first embryo-editing experiment in China to create HIV resistant children | There is no explicit invention for posting comments | Evolution; mutations; genes and genomes; heritable diseases; eugenics; genotype and phenotype; gene editing technics; gene disease treatments |
| | | How a Sick Chimp Led to a Global Pandemic: The Rise of HIV | Length: 10:19 Created: 2017 Total comments: 5420 | 197 comments | Informational & Exclamational video. The video presents HIV and AIDs definitions and history of origin and outbreak | There is no explicit invention for posting comments | Epidemiology; exponential growth; epidemic vs pandemic vs outbreak; types of virus (airborne vs. retrovirus); SARS, HIV and AIDS; vaccinations |
| CrashCourse | No of videos: 1108 No of views: 1032910177 No of subscribers: 9190253 | What Is Sociology?: Crash Course Sociology | Length: 9:41 Created: 2018 Total comments: 3425 | 133 comments | Informational & Exclamational video. The video provides definitions of Sociology, the study of sociology and its perspective | There is no explicit invention for posting comments | Whether sociology considered as science; replicability and verifiability; social vs natural scientific perspectives; research methodologies |

**Table 2**
Coding scheme.

| Discourse moves | Subtypes | Definition | Examples |
|---|---|---|---|
| Evaluation | Disagree | Attack or literally disagree with the previous comment | "… you're wrong. Do your research." |
| | Counter claim | Different opinion from previous speaker; does not attack | "… Okay, sorry about that, but it still killed millions and it did start with a single person spreading the disease. What do your statistics say about that?" |
| | Agree | Literally agree with the previous comment. | "You are absolutely correct …" |
| | Question | A comment that asks for clarification, elaboration or more facts | "By the way why did they destroyed all the sample and refused to send his sample to be tested?" |
| | Claim | Does not agree or disagree with previous, neutral | "I'm hoping to become a genetic engineer in the future and I really hope I will be able to help people with genetic conditions such as yourself, here's to a better world" |
| New/Repetition | | An idea that has not been (new) or has been (repetition) mentioned earlier in the discussion | |
| Grounds | Evidence | Information that helps to support or disapprove an idea (i.e., empirical data) | "If the methods of economists weren't objective & scientific, then they wouldn't be so heavily sought after by private companies–but they are. Every large firm in technology, banking, and finance employs teams of economists. Likewise, if their methods weren't valid, they wouldn't be highest paid people in the social sciences–but they are." |
| | Explanation | Clarification of causes, context, or consequences of ideas that were presented | "You guys are conflating so many definitions it's frustrating. You're conflating "Natural" sciences (as opposed to "Social") which deals with things that exists despite human institutions, with "Hard" science (as opposed to "Soft") which is a continuum/spectrum, rather than a binary categorization. Economics, sociology, political science and psychology are all considered social sciences because they study humans …. " |
| Evidence validation | External source | Outside information from newspaper, website, or another scientific source | "… Here you go. 25–50 million, NOT 200 million. THREE "sources" and I say that lightly without an actual expert signing off:<br>1) https://www.nationalgeographic.com/science/health-and-human-body/human-diseases/the-plague/2) https://www.forbes.com/sites/alexberezow/2014/05/12/black-death-the-upside-to-the-plague-killing-half-of-europe/#71cd921770d3<br>3) http://www.bbc.co.uk/history/british/middle_ages/black_01.shtml." |
| | Authority reference | Providing information based on a credible source | "Really? Because, again, the *National Science Foundation* considers economics–and other social sciences–to be science. I think they know something about science …" |
| | Personal experience | Justification based on personal experience | "… you already can go through IVF to ensure a condition is not passed to your children. *A cousin of mine* is a carrier for Hutchinson's Disease, and she had her son with IVF to make sure he wouldn't even be a carrier of the gene." |
| Emotional expressions | Negative emotional expression | Rudeness, offensive upsets | "… Wow, how stupid …"; "… Your "knowledge" is bullshit. 0 subscribers. What a joke …" |
| | Positive emotional expression | Empathy, positive feedback, encouragements | "… I appreciate your caution in reproduction, it might make you an as considerate parent."; "Very interesting" |

2001). Moreover, experiences that enable learners to challenge their beliefs through direct experimentation, observation, debate, and argumentation are especially fruitful (National Research Council, 2015).

Discussions among peers and between learners and teachers or guides play a central role in uncovering alternative conceptions, challenging interpretations, and fostering understanding (Fischer, Chinn, Engelmann, & Osborne, 2018). Instructors can ask learners to make predictions about observed phenomena, probe their rationales, and offer alternatives, and through such a process of deliberation and negotiation converge on more scientific conceptions (diSessa & Minstrell, 1998). Yet, not all discourse is equally productive (Lemke, 1990). Debate is key to productive discussions, but not if it is resolved through authority rather than evidence and persuasion (Lemke, 1990). Different studies in varying contexts converge on the idea that an argumentative stance – in which claims are not taken for granted and evidence and justification are valued as tools of adjudication – is most conducive to learning (Asterhan & Schwarz, 2016; de Vries, Lund, & Baker, 2002; Fischer, Chinn, Engelmann, & Osborne, 2018; Ford, 2012; Nussbaum, Sinatra, & Poliquin, 2008). Yet, learners rarely engage in such moves spontaneously (Asterhan & Schwarz, 2016; Fischer et al., 2018), and much scaffolding and support is needed to cultivate a productive discourse community (Forman, Ramirez-DelToro, Brown, & Passmore, 2017). Pushing learners to evaluate each other's statements explicitly, to explain the grounds on which they base their claims, and to provide evidence for their arguments is associated with better scientific understanding and learning (Clark & Sampson, 2008; Osborne, 2010). Similarly, while discourse plays a positive role in informal learning contexts, it is unclear how productive discussions can be for learning in the absence of a more knowledgeable discourse partner (Falk & Dierking, 2019; Rennie, 2014; Vedder-Weiss, 2017).

### *1.7. Research aims*

In light of the gap in knowledge regarding the actual educative capacity of online user-generated information and social media sites, alongside the paucity of research, we set out in this study to explore informal educative opportunities offered through user-generated information sites and social networking. Our study focused in particular on discussions in post-video comments on science videos on YouTube. In order to examine the educative value of this platform, we asked: Do spontaneous post-video public comments on YouTube reflect markers of knoweldge co-construction?

## 2. Methods

### *2.1. Research design*

In establishing the corpus of data for analysis, we looked for channels that have high traffic, using the YouTube search engine for the keyword "science." videos with high traffic were defined by the number of views and subscribers. Following this criteria, four leading channels emerged at the YouTube search engine: (1) the Kurzgesagt – In a Nutshell channel, which incorporates animations that discuss scientific, technological, political, philosophical and psychological subjects and describes different scientific phenomena such as black holes or what is light; (2) the science channel offers videos that facilitate learning about space, earth science and technology; (3) the Scishow channel seeks to answer unique scientific questions such as, "when you burn fat where does it go?" it covers the scientific fields of chemistry, physics, biology, and zoology, among others; (4) the CrashCourse channel provides courses about sociology, computer science, physics, ecology, and other subjects. While the science channel and Scishow produce a new video each day, Kurzgesagt – In a Nutshell makes one animation video per month (Table 1).

Subsequently, with the aim to assess users' discourse using post-video comments, we collected one or two videos from each channel (for a total of six videos). Following our particular interest in post-video comments as a potential arena for deliberation and knowledge co-construction, we chose videos that triggered the highest number of comments (as per Shifman, 2012). Then, within each video, we assessed each comment as a unit of analysis using a twofold coding perspective:

#### *2.1.1. Discourse moves*

A coding system was developed based on the work of Clark and Sampson (2008) and later expanded by Lu, Chiu, and Law (2011) to pinpoint a possible association between deliberation and knowledge co-construction. Comments were coded along three main dimensions for discourse moves. The first dimension of the code considered how the present comment evaluates previous comments; namely, whether it expresses disagreement, a counter claim, agreement, or a question (see Table 2 for code definitions and examples). Neutral informative posts that did not evaluate previous messages were coded as claims.

The second dimension distinguished between new and repetitive comments. This dimension noted whether the comment provided new insights or an idea that had not been mentioned earlier in the discussion; or alternately, whether it expressed repetition of prior ideas. The third dimension of the coding scheme focused on the level of grounds that users included to warrant their comments (Osborne, Erduran, & Simon, 2004). Specifically, each comment was classified as having no grounds, or as using only evidence or explanations as grounds. Our coding scheme categorized additional evidence classifications by introducing three types of evidence validation: evidence based on an external source, evidence that uses authority as proof, or use of personal experience to ground the comment (Soffer-Vital, Barzilai, & Tabak, 2015). Lastly, we also coded statements for their explicit emotional characteristics; namely, we coded offensive or hostile expressions as rude and emphatic or polite expressions as positive (Chiu, 2008; Chiu & Khoo, 2003).

A comment could be coded with only one code of the first, second, and fourth dimensions: (1) its type of evaluation; (2) whether the comment proposed a new idea or not; and (4) whether the comment included positive or negative statements. For the third dimension, we counted the number of evidence types and explanatory remarks that were used within each comment.

#### 2.1.2. Collaborative knowledge construction (CKC)

With the aim of conceptualizing the process of collaborative knowledge construction in asynchronous online discussions, we used Gunawardena, Lowe, and Anderson's (1997) coding scheme. This coding scheme has been both theoretically and empirically validated (see review, Lucas, Gunawardena & Moriera, 2014). This coding scheme assesses the process of knowledge construction in a series of successive (though not necessarily strictly sequential) phases that are viewed as moving from lower to higher levels of group collaborative interaction: (1) Sharing/Adding (e.g., a statement of observation or opinion; definition, description, identification of a problem); (2) Negotiating meaning (agreement or disagreement by providing restatements, by identifying inconsistencies, or by asking for clarification); (3) Elaborating (building on and expanding previous statements and meanings); (4) Proposing synthesis (synthesis of the discussion with the prospect of testing it and finalizing it); and (5) Consensus/Applying constructed knowledge (stating a summary of agreements, application of new knowledge, metacognitive statements of changes in knowledge or ways of thinking).

Each comment was categorized under one (and only one) of the categories for the phases of collaborative knowledge construction.

### 2.2. Reliability

Approximately 80% of the discourse was coded jointly by one of the authors and a research assistant. The remaining 20% was coded by each of these coders independently (the Cohen's Kappa coefficient was computed to be 0.82), and disagreements were fully resolved by discussion between the coders. According to McHugh (2012), these are high rates of agreement.

### 2.3. Data analysis

Since the CKC coding scheme incorporates five ordered categories, we used ordered logit regression to estimate the relationship between the discourse moves and knowledge construction level (Wise and Chiu, 2011). We also used a structural equation model to test all predictor effects simultaneously and to evaluate mediation effects of grounds' incorporation on knowledge construction level. For the mediation analysis, we implemented a method outlined by Hayes and Preacher (2014) for multi-categorical independent variable using the MPlus statistical software.

## 3. Results

Aiming to assess users' discourse and knowledge-collaborative interactions on YouTube, we collected 1530 comments from six post-video comments threads. The videos were selected on the basis of having received the highest number of comments among the videos on science channels (Table 1). 1019 (67%) comments were included in the final analysis. Users that posted more than 25 comments (114 comments in total) and strong language or irrelevant comments (i.e., commercial comments, 397 comments in total) were excluded from the current analysis. On average, each included user posted 1.48 (±1.56) comments, ranging from 1 to 16.

### 3.1. Discourse moves

The discourse moves analysis revealed that making neutral claims and posting counter-claims, i.e., expressing different opinions from previous speakers without any direct disagreement, were the most common evaluating interactions (see Supplemental Material 2). We also found that the discussions included more new ideas than old ideas (47% vs. 40%, respectively); and more explanations than evidence (64% vs. 34%, respectively, Supplemental Material 2). In addition, our analysis reveals that only 16% of comments included explicit emotional expressions; specifically, 12% of the total comments incorporated negative emotions (i.e., rude or offensive statements), and only 4% included positive expressions. Interestingly, 45% of the rude expressions were associated with disagreements, while 44% of the positive expressions were associated with neutral claims ($\chi2(8) = 86.275$, $p < .000$).

An analysis of users' tendency to incorporate evidence or explanations as part of their comments, using a one-way ANOVA with a Bonferroni adjustment, showed that disagreements and counter claims were significantly more often accompanied by evidence ($F(4, 914) = 15.555$, $p < .001$) and explanation ($F(4, 977) = 17.962$, $p < .001$) than by other evaluative statements (Table 3).

**Table 3**
Descriptive statistics (Mean, SD) of evaluative discourse moves by tendency to incorporate grounds or evidence validation.

| Discourse moves (Evaluations) | Grounds | | Evidence validation | | |
|---|---|---|---|---|---|
| | Evidence | Explanation | External source | Authority | Personal experience |
| Disagree | 0.81(±0.94) | 1.15 (±0.83) | 0.03 (±0.16) | 0.06(±0.23) | 0.07 (±0.25) |
| Counter claim | 0.67 (±0.99) | 1.03 (±0.88) | 0.08(±0.49) | 0.10 (±0.34) | 0.06 (±0.24) |
| Agree | 0.25 (±0.55) | 0.62 (±0.68) | 0.02 (±0.14) | 0.09 (±0.29) | 0.08 (±0.28) |
| Question | 0.14 (±0.45) | 0.2 (±0.57) | 0 | 0.02 (±0.13) | 0.02 (±1.14) |
| Claim | 0.37 (±0.67) | 0.9 (±0.84) | 0.05 (±0.41) | 0.02(±0.16) | 0.20 (±0.40) |
| Statistics (F) | 15.555*** | 17.420*** | 1.252 | 2.953 | 11.599*** |

***p < .001.

Only a small percent of comments included information that aimed to strengthen evidence credibility (21% total of all comments), using an external source (3.5%), authority (6%), or personal experience (11%) as evidence validation (see Supplemental Material 2). A one-way ANOVA with Bonferroni post-hoc revealed that claims were significantly more often accompanied by personal experience ($F(4, 1014) = 11.599$, $p < .001$) than by other evaluative statements (Table 3).

### 3.2. Knowledge construction

Collaborative knowledge construction analysis showed that the majority of comments were at the level of phase 1 of sharing/adding opinions, and Phase 2 of negotiating meaning (382 [37.5%] and 447 [44%], respectively). Only 122 comments (12%) reached Phase 3 of elaboration, 26 comments (2.5%) Phase 4 of synthesis, and less than 1% reached the highest level of knowledge construction, Phase 5.

For example, the following is a Phase 1 comment involving sharing/adding opinions from the "How a Sick Chimp Led to a Global Pandemic: The Rise of HIV" video: "No technology exists, and certainly did not in 1908, to create such a virus. Stop spreading conspiracy theories and give up your resentment."

An example of a Phase 2, negotiating meaning comment, is the following:

Manar M, That's why the guy said hypothesis, right? So, there is a possibility that it might be incorrect. If you think about it the hunter hypothesis is quite a sound one since it addresses one of characteristics of virus, which is it takes time for one virus to adapt and mutate. You cannot just get sick from a virus that is originally from another species. It takes decades of decades to makes it really dangerous for humans.

An example of a Phase 3 comment is the following:

@ Care2 Think, I passage cells on a weekly basis, I am a researcher, don't patronize me. There are many reasons the Polio vaccine theory is bunk at this point and has been for two decades. I will post the following article here and the journal article it refers to. Imo this kills any polio theory. Explain to me how the current pandemic strain can be traced back 100 years, 50 years before the polio vaccinations in Africa started occurring. Also, explain to me why SIV has NEVER been detected in the old vaccine stocks, and, why the SIV strain from the population of chimpanzees that is supposedly responsible for the pandemic (according to the Polio vaccine theory) is unrelated to HIV-1 strains today. The theory is junk just let it die already.

Fig. 1 represents an example of comments' sequence by the knowledge construction phases from the "How a Sick Chimp Led to a Global Pandemic: The Rise of HIV" video (Table 1). In Fig. 1, each square represents a comment, while the y-axis stands for phase of knowledge construction, and the x-axis stands for a post sequence within the thread. Notably, the knowledge construction sequence within the online discussion thread is not linear. While the pattern toward a higher knowledge construction level is clear (e.g., there are more comments in Phases 3 and 4 starting from comment No. 71 than at the beginning of the discourse; 9.5% vs 34.6%, respectively), there are still segments that return the discussion to the lower knowledge construction phases (for example, in comments No. 71–95, the knowledge construction phases sequence is: **333** 222 **3**21**4**2 112**4** **3**222**3**2 **44,** where each numeral indicates the phase, and each sequence of numerals separated by a space indicates comment number). Interestingly, on close inspection we found that users who advanced the discourse to the higher level of knowledge construction starting from comment No. 71 were the four most active participants in the current thread (each user posted 2.1 comments on average, while the four extremely active users posted 12.5 comments on average).

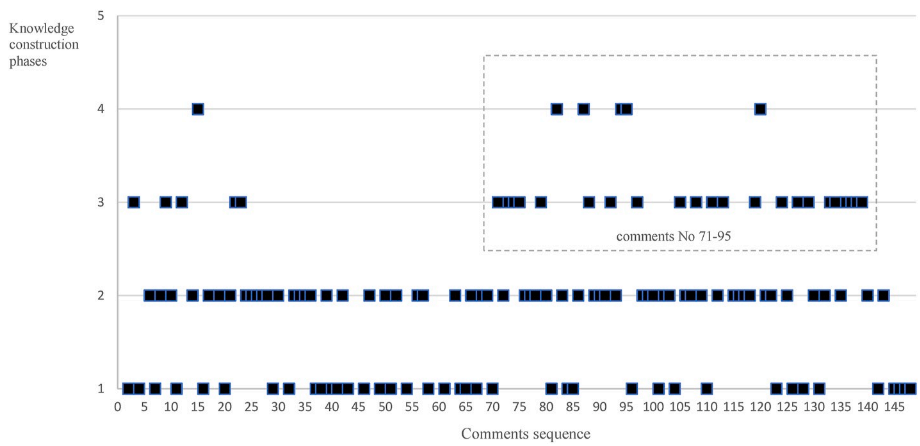


**Fig. 1.** Chronological visualization of the comments' sequence by knowledge construction classification from the "How a Sick Chimp Led to a Global Pandemic: The Rise of HIV" video. Each square represents a comment, the x axis represents a post sequence, and the y axis represents a phase of knowledge construction.

### 3.3. Knowledge construction and discourse moves

To identify whether and how discourse moves affect collaborative knowledge construction, we conducted an ordinal logistic regression. We adjusted the analysis for the different post-video discussions to control for the different videos' possible effect. The logistic regression models were statistically significant (see Table 4), explaining 56% (Nagelkerke R2) of the variance in knowledge construction level.

Model 1 shows that among evaluative discourse moves, disagreements had twice as many times higher odds to yield a higher level of knowledge construction than counter-claims and agreements, and eight times higher odds than neutral claims. Model 2 shows that a comment with a new idea had a higher probability to promote knowledge construction than an old idea. Model 3 proposes that incorporating a number of explanations or pieces of evidence as part of an argument was associated with a higher likelihood of promoting collaborative knowledge construction. The addition of evidence validation criteria to model 4 was not significant. Model 5 demonstrates that negative expressions were associated with lower probability to promote knowledge construction, while positive statements showed no significant effect.

Based on the above results, we used a path analysis to test the direct and indirect effects of discourse moves on knowledge construction, with only significant effects included. The model is shown in Fig. 2. The SEM showed a good fit ($X^2$ [df = 4] = 2.095, p = 0.71), comparative fit index (CFI) = 1.00, root mean squared error of approximation (RMSEA) = 0.00, standardized root mean residual [SRMR] = 0.03. The SEM effects were consistent with the ordered logistic regression results (Table 4), showing a direct effect between discourse moves of disagreement, counter-claims, and agreement, and knowledge construction level. Moreover, a significant partial indirect effect of incorporation of explanation and evidence into discourse was revealed only for disagreements (a1+a2 path * b1 +b2 path = 0.245, p < 0.01) and for counter claims (a1+a2 path * b1+b2 path = 0.153, p < 0.01).

## 4. Discussion

The goal of this research was to investigate the educative potential of the internet and social media, focusing on YouTube as a platform for informal science learning. We inquired into whether spontaneous post-video public comments on YouTube reflect markers of knoweldge co-construction. Overall, our results reveal that YouTube shows such promise in this regard.

### 4.1. Towards a process model of knowledge co-construction on YouTube

We examined whether, when, and how user-to-user joint interactions while reading and posting post-video comments on YouTube can generate situations that constitute knowledge co-construction. Our analyses extended beyond identifying instances and frequencies, to testing relationships between argumentation moves and markers of co-construction. Thus, our findings suggest a process model of informal knowledge co-construction on social media.

The apparent tendency of post-video discussions on YouTube to generate interaction moments that transcend information sharing

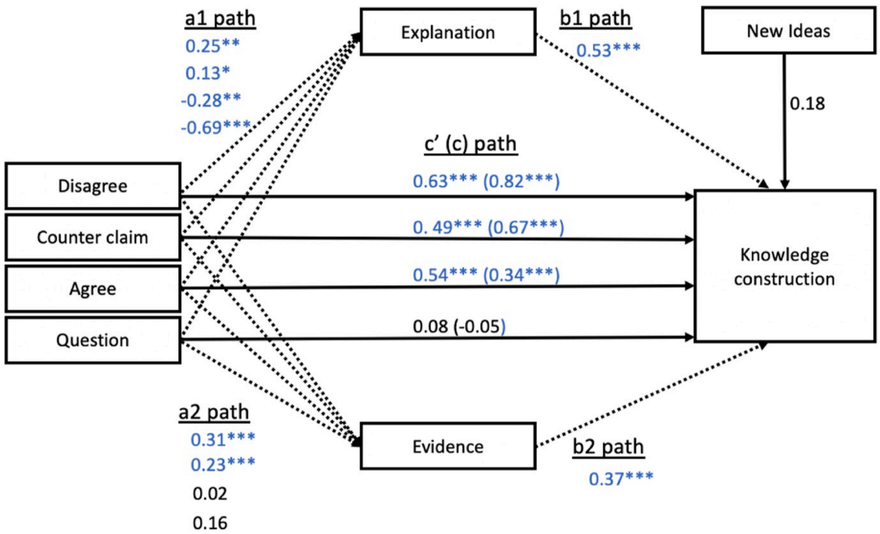


**Fig. 2.** Path diagram of final model predicting knowledge construction. The path involves standardized coefficients describing association between the multi-evaluative categories of discourse moves to the incorporation tendency of evidence and explanations; the b path presents standardized coefficients describing association between evidence and explanations and the level of knowledge construction; and the c'(c) path is the direct (total) effect.

and attain higher levels of negotiation can be explained through the discourse moves perspective. Our findings reveal that explicit expression of disagreements or counter-claims had the highest probability to advance collaborative knowledge co-construction, both directly and indirectly. The disagreements effect suggests that arguments that contain opposition are a necessary condition for higher forms of collective reasoning in online discourse. This is consistent with what is known about face-to-face and formal online argumentation (Asterhan & Schwarz, 2007; Mercer, 1995). However, the partial indirect effect of the mediation analysis also shows that it is not only about the opposition, but also about implementation of grounds as part of the comment. If a statement of disagreement incorporates evidence or explanation, it stimulates the author to engage in rise-above collaborative elaboration, which in turn will foster more constructive interactions. In contrast, users who were in agreements were likely to voice a common idea that was shared by many people earlier in the thread, and were less likely to include evidence or explanations; thus, their comments had a lower probability of advancing joint deliberation. Nevertheless, our results also show that while the most common type of evidence used in an attempt to strengthen credibility was based on personal experience, this form of evidence did not seem to have any impact on the collaborative constructive process.

Our results highlight not only the importance of disagreements and counter-claims as necessary conditions for higher forms of knowledge construction, but also the importance of engagement in the debate. As we mentioned above, the most active users reached the highest levels of knowledge co-construction (Phases 3 and 4). This suggests that motivated and engaged users are more likely to employ deep, reflective strategies and to reach the stage of conflict resolution. Therefore, it is likely that the social nature of YouTube, in which users are self-driven by interest and can participate anonymously, facilitates open expression of opposing views on the topic (Kilner & Hoadley, 2005). Engaging with content that supports the users' own interests and curiosity has been reported as the most important factor that impacts behavior, such as active posting of comments, in online discussions (Khan, 2017; Renninger, Hidi, & Krapp, 2014).

While we show that a greater legitimacy of different opinions relates to greater probability for constructive interactions, our analysis also suggests that rude emotional expressions hinder collaborative negotiation. These findings are consistent with the politeness theory of face-to-face interactions, which suggests that polite disagreements likely facilitate collaboration, but rude disagreements can hinder it (Brown & Levinson, 1987; Chiu & Lehmann-Willenbrock, 2016). Rudeness can reduce participation in online comment sections by making some users withhold important contributions or by making them withdraw entirely.

Our findings imply that in spontaneous informal settings, incongruities between prior individual knowledge and the presented information might motivate users to participate in collaborative deliberation by proposing novel insights and elaborations. We argue that in order to foster constructive interactions, it is necessary to facilitate challenges in the form of open individual disagreements, which in turn will stimulate a process of negotiation, modification, and collective deliberation (Chan, Burtis, & Bereiter, 1997; Chen & Chiu, 2008).

### 4.2. Knowledge co-construction in formal and informal environments

Much research has been conducted on the process and behaviors involved in asynchronous online discussions in formal educational settings. This study adds to the existing body of knowledge by evaluating the landscape of spontaneous and informal interactions that emerge as part of the social epistemological nature of YouTube. In demonstrating what leads to knowledge co-construction in informal settings, and in comparing these patterns with those found in formal settings, we contribute to the understanding of both formal and informal learning.

By applying the collaborative knowledge construction coding scheme (Gunawardena, Lowe, & Anderson, 1997) to conduct quantitative content analysis and sequential analysis, we were able to unfold how knowledge co-construction advanced during the post-video discourse. Our findings revealed a high proportion of posts (37.5%) at Phase 1 of sharing information, which is similar to results of previous studies about synchronous and asynchronous online discussions in formal settings (Chen, Chen, & Tsai, 2009; Cress, Stahl, Ludvigsen, & Law, 2015; Gunawardena et al., 1997; Lucas, Gunawardena, & Moreira, 2014; Wise & Chiu, 2011). However, interestingly, in contrast to past studies' findings, we show a greater proportion of posts involving meaning negotiation at Phase 2. While analyses of online debates in formal settings report only a small percentage of posts that advanced to Phase 2 (i.e., 9.7%, De Wever, Van Keer, Schellens, & Valcke, 2009; Lucas & Moreira, 2010), our results show that a substantial number of comments (44%) advanced to the negotiation phase. This finding suggests that informal online joint interactions can launch discussions wherein participants engage not only to express their own ideas but also to consider existing ideas within the thread.

Following the high proportion of posts at lower phases of knowledge co-construction (Phases 1 and 2), only a small proportion of comments reached the higher levels of knowledge co-construction represented by Phases 3 (elaboration), 4 (synthesis), and 5 (consensus). Indeed, a pattern in which the proportion of posts decreases with each successive knowledge co-construction phase is consistent with the literature (Gunawardena et al., 1997; Lucas et al., 2014). However, interestingly, we do show that some participants – the ones who were most active in posting comments – succeeded during their collective deliberation to reach the highest knowledge co-construction levels (Phases 3 and 4) of elaboration and synthesis.

### 4.3. Open questions and limitations

There are a number of open research questions to explore. First, the educative value of YouTube hinges on the reliability of its content. While ranking markers for the video itself seem to pose a fairly good indicator of reliability, such formalized and aggregating

**Table 4**
Multilevel, ordered logit regression models predicting knowledge construction.

| | | Model 1[a] | | | Model 2[a] | | |
|---|---|---|---|---|---|---|---|
| | | β (SE) | Wald $\chi2$ (df = 1) | OR (CI) | β (SE) | Wald $\chi2$ (df = 1) | OR (CI) |
| Evaluation | Disagree | 2.17*** (0.21) | 107.33 | 8.75 (5.80–13.19) | 2.21*** (0.22) | 97.37 | 9.07 (5.85–14.06) |
| | Counter-claim | 1.69*** (0.18) | 90.41 | 5.47 (3.85–7.76) | 1.72*** (0.19) | 81.41 | 5.61 (3.85–8.15) |
| | Agree | 1.13 *** (0.26) | 19.31 | 3.10 (1.87–5.15) | 1.64*** (0.28) | 32.55 | 5.15 (2.93–9.05) |
| | Question | 0.19 (0.31) | 0.39 | 1.21 (0.66–2.23) | 0.35 (0.39) | 0.92 | 1.42 (0.69–2.94) |
| | Claim | Reference | | | Reference | | |
| New/Old idea | New Idea | | | | 1.14 *** (0.15) | 58.89 | 3.13 (2.34–4.20) |
| | Old Idea | | | | Reference | | |
| Grounds | Evidence | | | | | | |
| | Explanation | | | | | | |
| Evidence validation | External source | | | | | | |
| | Authority reference | | | | | | |
| | Personal experience | | | | | | |
| Emotional expressions | Negative emotions | | | | | | |
| | Positive emotions | | | | | | |
| | No emotional expressions | | | | | | |
| Nagelkerke R2 | | 0.21 | | | 0.28 | | |
| Model fit | | $\chi2(14) = 201.83$, $p < .001$ | | | $\chi2(15) = 257.716$, $p < .001$. | | |

**p < .01, ***p < .001.
aThe model is adjusted for the different discussions following different videos.

ranking markers do not exist for in-comment reactions to other comments. Thus, the quality of the post-video deliberation, and the ability to gauge reliability, require further research. Second, aside from self-reports, there is a paucity of measures for documenting evidence of learning, especially for conceptual learning, which has received little attention in the study of social media. Third, while the current research focus was on opportunities to learn, it would be beneficial to measure learning outcomes directly. Lastly, another potential avenue for co-construction in YouTube is through interaction between those who post the videos and their audience. Hattingh (2017), for example, describes how in a subsequent video post, a presenter referred back to questions he got from subscribers regarding an earlier video and explained concepts with which they had struggled. Deschamps (2014) proposed that those comments present an opportunity for users to "transform the narrative by presenting new information … by challenging arguments, relaying new ideas, offering counterfactuals or by attempting to re-frame the discussion" (p. 345).

The present study has several limitations that should be taken into consideration. First, YouTube API does not make users' demographic data available; therefore, future studies should look into variables such as gender and age to evaluate their effect on deliberation processes. Additional limitation includes coding granularity and the difficulty to differentiate quality of the comments and to detect the exact sequence of comments (who refers to whom within the thread). Although the chosen model in our analysis, presented by Gunawardena et al. (1997), is suitable for conceptualizing and assessing knowledge construction processes in temporal online deliberations, other frameworks to investigate knowledge construction (e.g., Pena-Shaff & Nicholls, 2004; Weinberger & Fischer, 2006) might yield different insights. In addition, in order to elucidate the user-to-user joint interactions, we analyzed videos that triggered the highest number of comments. We suggest that future analyses should compare our findings with those stemming from analyses of videos that received a lower number of comments. Furthermore, our coding scheme did not capture the accuracy and quality of the comments; therefore, further studies should consider whether the content of the messages is accurate or not, and evaluate the effect of comment quality on the discourse process. Finally, additional methodological approaches should be incorporated, such as sentiment analysis and network analysis (Lebedev & Sharma, 2019; Thelwall, 2018).

### 4.4. Conclusion

This is one of the few studies in knowledge construction that has been entirely dedicated to identifying and characterizing the informal interactions that emerge on YouTube. This type of empirical investigation is important for disentangling the tensions between the allure of social media and popular belief in its efficacy for informal learning, and its prevalent transmission-based qualities, which are less conducive to learning. Though future research directed at measuring actual learning is needed, these everyday, self-regulated, informal opportunities to learn that are driven by an authentic need or interest, offer, as shown above, precursors for collaborative learning through deliberation in the post-video comments. Thus, social media, despite its transmission-based content, bears potential for efficacious informal learning and merits additional research. Such research is especially important given the growing need for informal learning opportunities.

| Model 3[a] | | | Model 4 [a] | | | Model 5 [a] | | |
|---|---|---|---|---|---|---|---|---|
| β (SE) | Wald χ2 (df = 1) | OR (CI) | β (SE) | Wald χ2 (df = 1) | OR (CI) | β (SE) | Wald χ2 (df = 1) | OR (CI) |
| 1.78*** (0.24) | 52.75 | 5.95 (3.68–9.64) | 1.82*** (0.24) | 54.42 | 6.19 (3.81–10.05) | 2.03*** (0.24) | 61.20 | 7.60 (4.57–12.63) |
| 1.39*** (0.20) | 44.17 | 4.02 (2.67–6.07) | 1.39*** (0.20) | 44.07 | 4.03 (2.67–6.08) | 1.47*** (0.21) | 47.79 | 4.37 (2.87–6.64) |
| 1.45*** (0.30) | 22.55 | 4.29 (2.35–7.82) | 1.45*** (0.30) | 22.37 | 4.29 (2.34–7.86) | 1.43*** (0.30) | 21.52 | 4.19 (2.28–7.68) |
| 1.35** (0.42) | 10.00 | 3.88 (1.67–9.02) | 1.40** (0.43) | 10.66 | 4.06 (1.75–9.43) | 1.38** (0.43) | 10.18 | 3.97 (1.70–9.29) |
| Reference | | | Reference | | | Reference | | |
| 0.68*** (0.16) | 15.79 | 1.94 (1.40–2.70) | 0.69*** (0.16) | 16.32 | 1.98 (1.42–2.76) | 0.69*** (0.17) | 16.37 | 1.99 (1.42–2.78) |
| Reference | | | Reference | | | Reference | | |
| 0.93*** (0.12) | 59.66 | 2.54 (2.00–3.22) | 0.90*** (0.12) | 54.68 | 2.47 (1.94–3.14) | 0.86*** (0.12) | 48.89 | 2.36 (1.85–3.00) |
| 1.25*** (0.12) | 105.64 | 3.49 (2.74–4.44) | 1.25*** (0.12) | 103.97 | 3.48 (2.74–4.43) | 1.24*** (0.12) | 102.78 | 3.48 (2.73–4.43) |
| | | | 0.68 (0.38) | 3.18 | 1.98 (0.93–4.21) | 0.63 (0.38) | 2.71 | 1.89 (0.88–4.04) |
| | | | 0.33 (0.29) | 1.23 | 1.39 (0.77–2.51) | 0.36 (0.30) | 1.42 | 1.43 (0.79–2.58) |
| | | | 0.04 (0.31) | 0.02 | 1.04 (0.56–1.94) | −0.02 (0.31) | 0.00 | 0.97 (0.54–1.81) |
| | | | | | | -.66[a] (0.26) | 6.49 | 0.51 (0.30–0.86) |
| | | | | | | 0.49 (0.41) | 1.42 | 1.63 (0.73–3.64) |
| | | | | | | Reference | | |
| 0.55 | | | 0.55 | | | 0.56 | | |
| χ2(17) = 534.207, p < .001. | | | χ2(20) = 539.244, p < .001. | | | χ2(22) = 547.606, p < .001. | | |

## Credit author statement

The first author, Ilana Dubovi, collected, and acquainted the data, analyzed and interpreted the data, drafted and conceptualized the manuscript. The research idea was initiated by Iris Tabak, in addition she facilitated collection of the data, provided insight into the data analysis and its interpretation, drafted and conceptualized the manuscript. All authors read and provided critical revisions of the manuscript.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2020.103939.

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