# Mapping Concepts Engineering Students in China Use to Think about Ethics

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## Abstract

To better understand how engineering students think about ethics across cultures, and improve education in engineering ethics on this basis, a website was developed to host educational contents and conduct research. The site can facilitate large-scale, qualitative research using methods employed by the computational social sciences and digital humanities. To demonstrate its potential value, this paper describes a preliminary study using network analysis and semantic maps to explore the responses of engineering students (N=70) in China to two course-related prompts: give an example of a behavior you consider unethical; explain what makes this behavior unethical. Preliminary results seem to suggest that engineering students in China conceive of unethical behaviors as ones where companies negatively affect people through their products, and that the harmful, other-regarding nature of these behaviors is what makes them unethical. The implications of these results are discussed, as well as shortcomings of the current study and directions for future work.


## Introduction

This paper shares second-year results of ongoing work to develop a website hosting educational contents on global engineering ethics and collecting information related to cross-cultural moral psychology. Using methods employed by the computational social sciences and digital humanities, it presents and discusses concepts engineering students in China use to think about ethics-related issues. These methods have been used to explore regional differences in values from obituaries, folk conceptual dualism, and the authorship and organization of texts, for instance, but not the ethics-related views of engineering students.[1]–[3]

Data for analysis comes from free-response, reflection questions about topics interspersed throughout readings on global engineering ethics. These are hosted on https://cgae.sjtu.edu.cn, a website used for a semester-long, two-credit hour course on engineering ethics, "Global Engineering Ethics," at the University of Michigan-Shanghai Jiao Tong University Joint Institute (UM-SJTU JI), a foreign-Chinese educational venture in Shanghai, China. Versus fixed-response, multiple choice questions – generally used for large-scale studies – those in this work do not limit possible responses. That is beneficial, since this research involves participants from different cultures, and cross-cultural research runs the risk of imposing inappropriate theoretical constructs and paradigms.[4] Additionally, versus mere research items, these questions allow students to reflect on what they already know and think about ethics-related concepts in relation to engineering and technology specifically.

To discern the concepts engineering students use to think about ethics, answers to free-response questions were analyzed using network analysis and semantic maps. This consists in identifying words that appear in free-response answers, and the natures of relations between these words.

Although the website hosts contents and has collected information on topics ranging from the nature of culture, safety, business, and rights, this paper presents schema about two prompts regarding the nature of ethics: 1. Give an example of a behavior you consider prototypically unethical (what prompt) and 2. Explain what makes this behavior unethical (why prompt). These prompts were used as a starting point, since a growing body of work has explored how

conceptions of ethics vary across and within cultures, among engineering students, and how this would be important to engineering and technology ethics.

Participants from China and other East-Asian cultures have been found to moralize behaviors associated with loyalty, adherence to authority, and sanctity to a greater extent than those from Western cultures.[5]–[10] This same difference appears between political conservatives and liberals, and those of lower and higher socioeconomic status.[11], [12] Whereas participants from Western cultures have been found to conceive of immorality primarily in terms of harmful behaviors, those from China have been found to conceive of immorality in terms of breaches in etiquette and convention.[13], [14] Methodologies within moral psychology have been criticized, for instance, because the focus of research is overly narrow – primarily examining consequentialist versus deontological judgments – and dilemma types are unrealistic or difficult to understand, such that responses are unlikely to reveal much about the normative domain or ethical reasoning.[15]–[17] This study addresses these concerns by allowing participants to articulate examples of unethical behaviors and what makes these behaviors unethical for themselves.

Regarding engineering specifically, Carla Zoltowski and colleagues are engaged in ongoing research to map the different ways that practitioners conceive of ethics in engineering.[18] This is important, since earlier work by Robert McGinn found widespread disagreement among engineering students and practitioners about what constitutes ethics, indicative of a potentially pernicious relativism.[19] This earlier study by McGinn was replicated with engineering students in China, finding that Chinese engineering students conceive of ethics in contradistinction to the law, where ethics deals with issues of right and wrong not covered by the law.[20] Such cultural and social differences likely influence the adoption and development of different codes of engineering ethics across cultures and countries.[21] Brad Stappenbelt reported that engineering students in Australia judged as least important principles most important to ethical engineering – such as only performing within one's area of competence and life-long learning – because of the potential disconnect between these principles and commonsense understandings of ethics.[22]

Given these findings, it is important to better understand what engineers and those working with technology think about ethics – and how conceptions of ethics differ across cultures, regions, and countries – to identify and address problems that could arise from these differences. This study represents a novel way of addressing these questions on a largescale and over time. Although not a replacement of qualitative methods involving in-depth interviews, extended reflection essays, or questionnaires, for instance, the approach presented here represents a supplement to these methods, where resources to conduct interviews, read essays, or analyze and code responses are substantial and potentially lacking.[23], [24] Since this study was exploratory and the research is ongoing, no specific hypotheses were made.

**Method**

*Participants*. Participants were undergraduate engineering students at UM-SJTU JI. UM-SJTU JI was founded in 2006 and has majors in mechanical engineering (ME), electrical and computer engineering (ECE), and material science (MS), which are modelled on those of the University of Michigan (UM). UM-SJTU JI's programs in ME and ECE are ABET accredited. Admission of domestic students is based of having been first admitted to Shanghai Jiao Tong University

(SJTU), based on high school grades or Gaokao scores, the Chinese college-entrance exam. Admission of international students is similar to UM, based on high school grades and SAT and/or ACT scores. SJTU is consistently ranked as one of the top four universities in China, and has top programs in engineering. Tuition for the UM-SJTU JI is higher than that of SJTU, currently 75,000 RMB (approximately 10,000 USD) per year, such that study participants tend to come from more affluent socio-economic backgrounds. The official language of the UM-SJTU JI is English, and all course instruction takes place in English. As a result, all participants in this sample have high English-language proficiency.[1]

The inclusion of responses in the study was voluntary and non-incentivized. At the beginning of the semester, students registered on the course website (https://cgae.sjtu.edu.cn) for "Global Engineering Ethics," filling in demographic and other background information. Only the responses of students who read and consented to have their responses aggregated for research purposes are included here. In total, 89 students were enrolled in two sections of "Global Engineering Ethics" during the Fall 2019 semester. "Global Engineering Ethics" is a required course that students generally take during their junior and senior years, and fulfills ABET student outcomes 2-5.

A total of 79 students consented to have their answers used for research purposes. The responses of seven students who failed to complete demographic information were excluded, for a total sample size of 70 (17 females), with an average age of 20.8 years old. The citizenship of all participants was Chinese (People's Republic of China) except for three – one with citizenship in Ghana, South Korea, and the United States, respectively. Similarly, all identified as Asian, except for one who identified as black, and all were native-Chinese speakers, except for four, two native-English speakers, one Korean, and one French.

*Materials and procedure*. Data for analysis comes from free-response, reflection questions interspersed throughout readings hosted on https://cgae.sjtu.edu.cn. Questions and readings come from the text *Global Engineering Ethic*s, by Heinz Luegenbiehl and Rockwell Clancy, used with the permission of the authors and publisher.[25] On average, students were assigned to read and complete the reflection questions of one chapter per class. At the end of the semester, answers and corresponding demographic information were downloaded into spreadsheets.

Text responses to the what and why prompts were first spell-checked and standardized for US English, and then tokenized using the unnest_tokens function in the tidytext package for R.[26] This function strips the text of punctuation, converts upper- to lower-case letters, and assigns terms ID's based on the participant from which they come. The anti_join function was then applied, to remove common stop words. Lists of terms appearing in the responses were then reviewed and synonyms standardized. The shortest variants of words were used, for example, singular versus plural nouns ("technology" rather than "technologies") and the root form of verbs

[1] Although the English-language skills of participants in this study were not assessed, in 2017, the UM-SJTU JI conducted a survey of undergraduate students who took the TOEFL, finding the mean score was 102.45 (N = 186; SD = 6.19). Of undergraduate students who take the TOEFL, this score falls in approximately the 85th percentile.[32]

(“harm” rather than “harms,” “harmed,” or “harming”). Although this runs the risk of merging terms with distinct meanings, it would be preferable to missing relations between them.

Word lists were then turned into adjacency matrices and loaded into Gephi, an opensource software for network analysis, to create and manipulate sematic maps. In each matrix, the cooccurrence of terms in different participant responses were treated as undirected edges in a network, with edge weights equal to the number of times a word cooccurred in responses by different participants. A standard ForceAtlas layout was used, preventing nodes and labels from overlapping, and words were grouped by a modularity measure (resolution = 1.0). Node and edge colors reflect communities, and node and label size are based on term centrality within a network. The color and width of edges represent the frequency of word cooccurrence between different participant responses.

**Results**

Responses to what prompts were between 1 and 135 English-language words, with a mean response length of 20.8 words (SD = 23.2). This resulted in a network of 411 nodes with 5142 edges, and an average path length of 2.42. The network density was 0.06, with a clustering coefficient of 0.89 and modularity of 0.57. In total, 15 communities were identified.

Responses to the why prompt were between 3 and 106 English-language words, with a mean response length of 27.6 words (SD = 23.4). This resulted in a network of 396 nodes with 9562 edges, and an average path length of 2.29. The network density was 0.06, with a clustering coefficient of 0.86 and modularity of 0.53. In total, 10 communities were identified.

Since graphs of these networks are too big to meaningfully discuss, a set of simplified graphs were developed for each network (Figure 1 and 2). The graphs were filtered using the giant component in Gephi, keeping only components with the most nodes, and further excluding any nodes with a connection of less than two. The ForcedAtlas layout was applied again, as well as the modularity measure (Figure 1 and 2).

**Figure 1** Filtered network of terms used to respond to the what prompt. Node and edge colors reflect communities, and node and label size is based on term centrality within the network. The color and width of edges represent the frequency of word cooccurrence between responses.

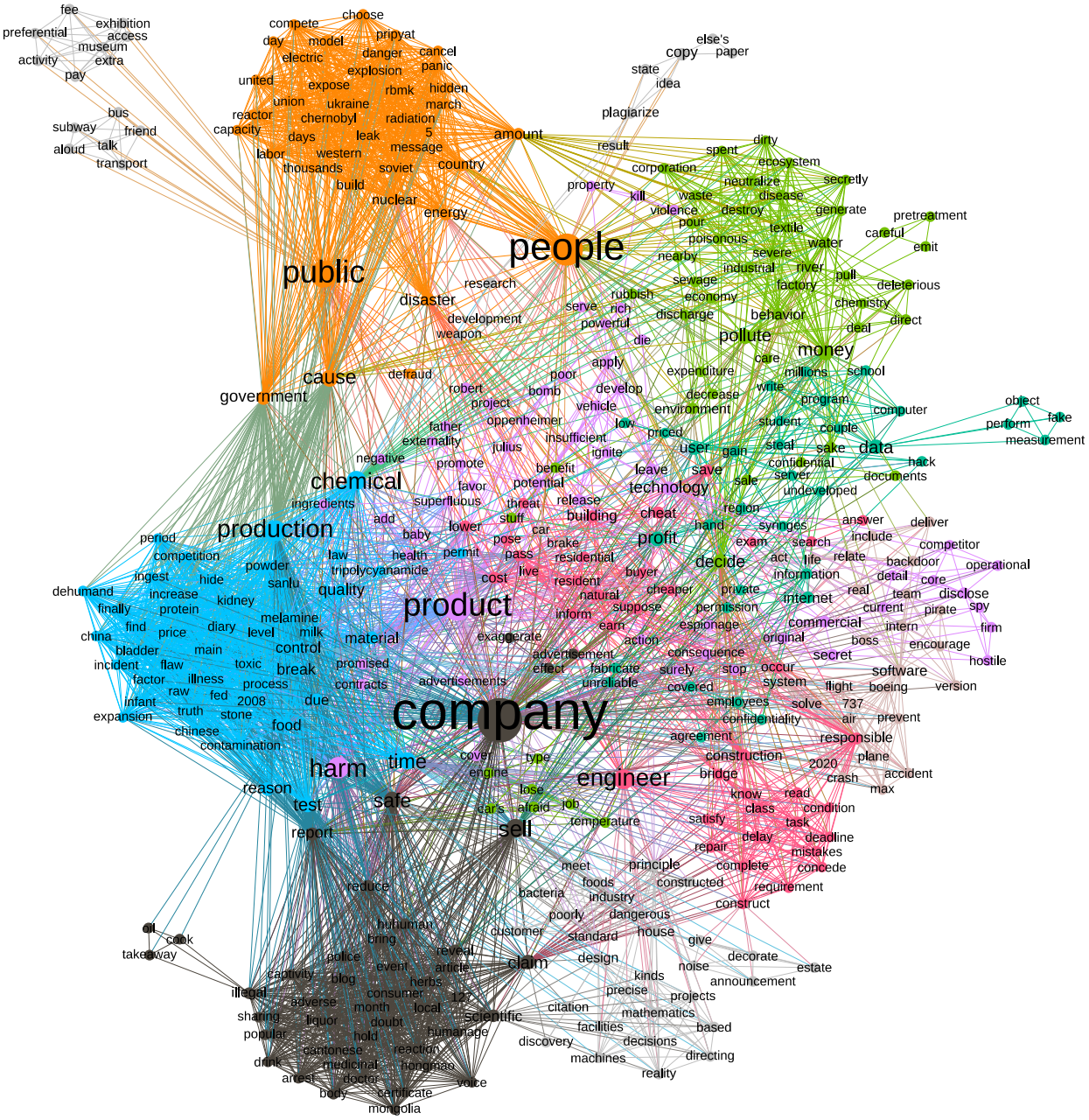
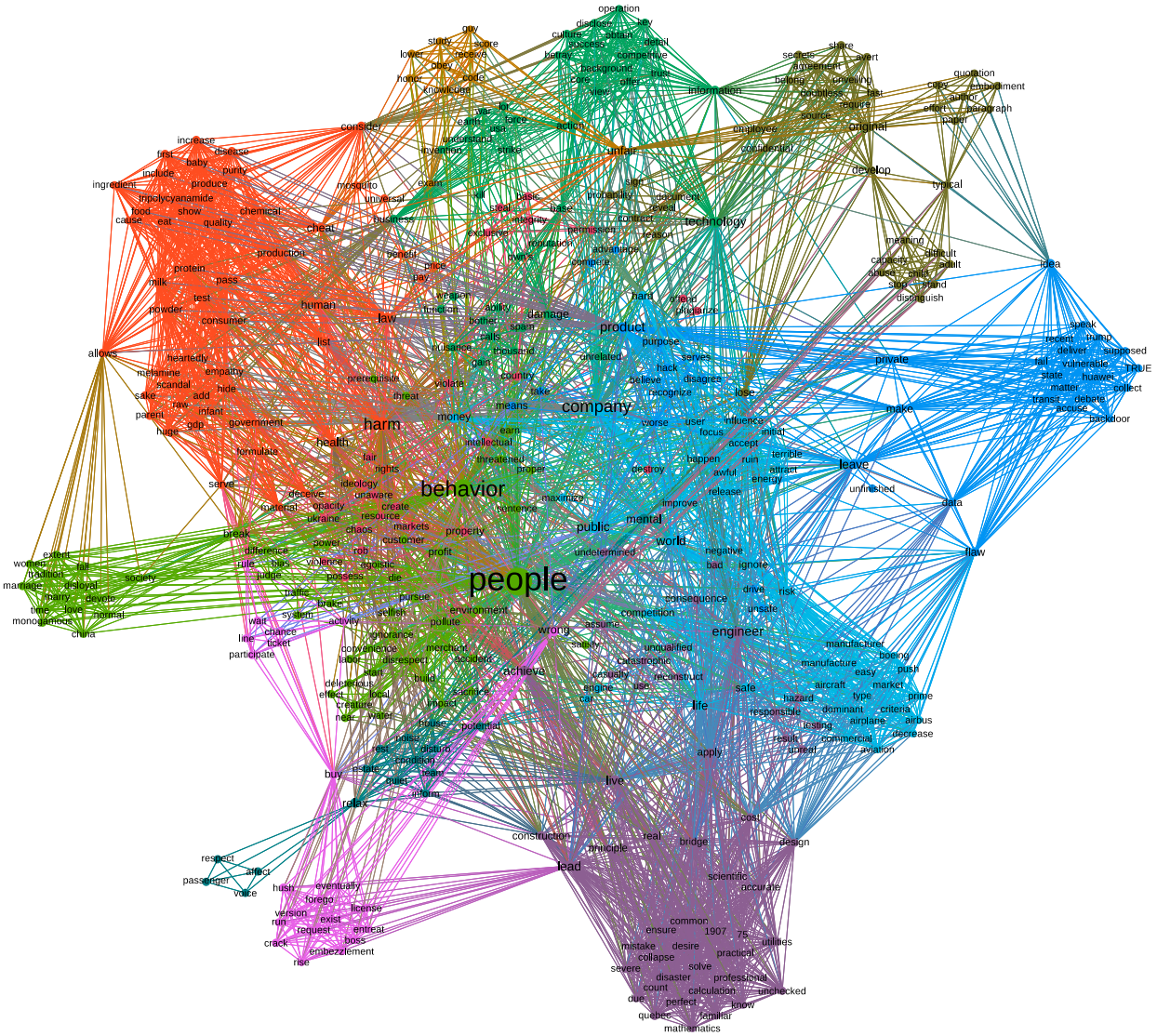


**Figure 2** Filtered network of terms used to respond to the why prompt. Node and edge colors reflect communities, and node and label size is based on term centrality within the network. The color and width of edges represent the frequency of word cooccurrence between responses.



**Discussion**

These results provide a novel way of exploring how engineering students conceive of ethics, and this research could be used to facilitate ethics education.

Regarding examples of unethical behaviors, "company" was the most used and central term, followed by "people," "public," and "product" (Figure 3). Since these do not refer to behaviors directly, and the sample size of this study was only 70, the authors read through these responses. Based on this review, these most-used, central words indicate that participants generally conceive of unethical behaviors as ones by companies, affecting people and the public. Examples include the following: "Some Internet company take their users private information without permission and sell them for profit." "Produce products of poor quality in the favor of more profits." "For example, use chemicals that are not permitted in law in food production to pass the quality test while lowering the cost such as the tripolycyanamide in milk powder production."

Term clusters provide further evidence of this focus. For instance, the cluster of terms in blue that includes "infant," "sanlu," and "kidney" (Figure 1) clearly refers to the 2008 China milk scandal, where six children died and thousands more were hospitalized after melanine was put in baby formula. Despite occurring more than ten years ago, when study participants were themselves still children, this remains a well-known and prototypical example of an unethical behavior for Chinese engineering students. Similarly, the cluster of terms in orange, which includes "ukraine," "reactor," and "radiation," refers to the Chernobyl nuclear powerplant explosion. Although not a company, this example was most likely salient because, in 2019, HBO produced a miniseries based on this event, to which students frequently referred throughout the course. The cluster of terms in green, on the upper right-hand side of the graph, includes "pollute," "money," and "river." Although not any specific event, this cluster likely refers to examples of environmental denigration, where economic benefits come into conflict with environmental costs.

In general, the terms used to describe example of unethical behaviors are largely what might be expected in engineering ethics, although the prompt did not refer to engineering or technology specifically. Participants likely inferred the question was concerned with engineering or technology, given their enrollment in a course on engineering ethics. Responses to the prompts analyzed in this study were included in the first reading/response assignment, completed after only the first day of class. As a result, the responses analyzed here likely represent the kinds of behaviors students genuinely believe fall within the sphere of engineering ethics, based on their previous knowledge and/or experience. Students are unlikely to have given these answers simply because they believed they were the correct one, based on what students had already learned in the course.

Turning to what makes these behaviors unethical, "people" was the most often used, central term, followed by "behavior," "company," and "harm" (Figure 4). Referring again to the responses, these words seem to indicate that unethical behaviors are primarily conceived as other-regarding actions that harm people. Prototypical responses include the following: "First, the behavior of hacker causes damage to the privacy of the users as well as the interest of the owner of servers…" "To maximize profit, the company ignores public health. The right of the

life should be placed higher than money." "This behavior pollutes the environment, which damages to the interests of everyone."

Examining the communities in this network (Figure 2), the red cluster on the left contains many of the same terms related to the China milk scandal cluster, for instance "melanine," "powder," and "infant," with numerous links to "harm" and "law." That indicates that this event was unethical since it harmed people and broke the law. Similarly, the blue cluster on the far right includes the terms "backdoor" and "collect," with links to "private" and "data," all of which would be related to cyber security and data collection. Therefore, cyber security, data collection, and user privacy would be less central to understandings of ethics in this sample, since terms related to these ideas lie further away from the network center.

Going forward, gathering more responses, from different types of participants will be beneficial. Participants in this sample were almost exclusively Chinese. As a result, examples of unethical behaviors and explanations of what makes these behaviors unethical might not be representative of other populations. History and culture likely affect examples listed and criteria provided. For instance, US engineering students are unlikely to list the 2008 China milk scandal as a prototypically unethical behavior. However, there might be other incidents similarly impactful to specific national groups, for instance, the Deepwater Horizon/BP oil spill. Further, rather than conceiving of unethical behaviors as ones by companies affecting people and the public, US participants might be more likely to conceive of unethical behaviors in terms of the intentions of individuals.[27] Interestingly, the term "justice" was not used to respond to either prompt – "rights," "fair," and "unfair" comprised only small nodes in the why network. Towards this end, the authors plan to explore website data using theories from moral psychology, for instance, Moral Foundations Theory (MFT) and the developmental stages/schema framework underlying the Defining Issues Test (DIT).[5], [12], [28]–[31]

This research also has educational implications: By better understanding what students already think and know about ethics, instructors are in a better position to tailor educational contents, for example, discussing or conducting case studies on incidents with which students are already familiar. This familiarity and potential emotional connection can be used to better engage students, deepening their appreciation for and understanding of ethics. Pedagogical activities based on this research could be useful to practicing engineers working across cultures and countries as well. Carrying out this exercise with practitioners, presenting and discussing the sematic maps in real time, provides an entertaining way for participants to learn from and about each other, highlighting points of convergence or divergence in understandings of ethical engineering.

**Conclusion and future work**

The use of https://cgae.sjtu.edu.cn can improve engineering ethics education, better understanding what engineering students and practitioners know and think about engineering ethics-related concepts, adapting curricula and behaviors accordingly. Versus mere quantitative research, the use of this site facilitates large-scale, long-term qualitative studies, recruiting participants from across the world and over time, using methods associated with the computational social sciences and digital humanities. However, as this work is only beginning

and the results reported here are preliminary, this study suffers from a number of shortcomings that will be addressed in future research.

The study sample was relatively small and homogenous, comprised by only 70 participants, all undergraduate engineering students, almost exclusively Chinese. Since almost none of the participants were native-English speakers, and all study materials were in English, the possibility exists of participants having misunderstood prompts or been limited in their ability to reply effectively. Going forward, more, different types of participants will be recruited. Efforts are currently underway to translate study materials into Chinese, so Chinese-language responses can also be collected. Although the website collects demographic information, this information was not used in the current study. Future research will explore the relation between free-response answers and demographic variables as well, including native language. The present study merely sought to provide an example of one way the site might be used. More data will be collected, and the authors plan to continue analyzing and presenting ways this site can be used to conduct research and improve education.

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