# The Potential of Using Semantic Similarity as an Auditing Tool to Restore Neutrality and Credibility to Public Scientific Grant-Giving Institutions

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## 1 Introduction

For several years now, there has been a steady accumulation of evidence that suggests a sharp decline in the public trust of both scientific and educational institutions. [4] [2] At least some of the reason for this decline in public trust can reasonably be attributed to the perception that these institutions have become far less politically neutral than they were originally created to be. More than three years ago, I published work demonstrating the increasing politicization of grants issued by The National Science Foundation.[11] Last year, a former colleague at Northwestern University, Igor Effimov (and co-authors,) published work connecting the decline in trust of scientific institutions to their increasing politicization. [3] In order to effectively restore public trust in these important institutions, more effort should be made to preserve political neutrality. To be able to do this, it is necessary that the inner workings of these institutions be made more transparent, such that the public, and their democratically elected representatives, can have effective oversight.

In 2017, Lyle Asher wrote an op-ed in The Chronicle of Higher Education that detailed the ways in which ideas from schools of education were migrating into university administration, making universities more politicized, more dysfunctional, and less effective at educating. [1] In his book, Science Fictions: How Fraud, Bias, Negligence, and Hype Undermine the Search for Truth, psychologist Stuart Ritchie details several ideas that have large purchase in schools of education, but largely fail to meaningfully replicate when tested at appropriate scales: mindset theory, stereotype threat, etc. In addition to these ideas, schools of education are rife with ideas from people such as Brazilian Maoist Paolo Freire, that promote alternative epistemologies and pedagogy that are entirely incompatible with the ways of producing and transmitting knowledge that have driven the impressive amount of scientific progress we have seen over the last three centuries. Many of these ideas also spring from explicitly radical political traditions and their increasing prevalence in science, education and science education is likely responsible for a much of the politicization of these institutions we are seeing.

## 2 Semantic Similarity

Semantic similarity measures how closely related in meaning two pieces of text are. Recent advances in machine learning have produced quite accurate methods of measuring the semantic similarity of documents. One of the more common methods currently in use, first encodes text into long lists (vectors) of numbers that represent the different concepts within the text. It then takes a measure called cosine similarity, which tells us the angular distance between two such vectors in high-dimensional space. This method does an impressive job of measuring the semantic similarity of documents. We can then use the semantic similarity score to search through a large corpus of text to find documents, pages, passages, paragraphs, etc. that are similar to some target text.

## 3 Using Semantic Similarity as an Auditing Tool

Corpora of text, like archives of government documents, can be incredibly large. The cost in labor of doing large-scale audits that involve reading and manually coding the content or quality of documents can be immense, and often prevent such audits from ever taking place. Semantic similarity can be a very useful (and relatively cheap) tool when put to such purposes. These technologies derived from large language models (LLMs) are not perfectly infallible (nor are human auditors,) but they can be used to quickly locate desired content within large corpora that human auditors can then further scrutinize. These methods can also be used to take aggregate statistical measures of the content of particular collections of text that can provide useful information.

## 4 A Preliminary Experiment: Critical Theory Content from Ed Schools in NSF Grant Abstracts

Having done previous work on NSF grants and politicization, I decided to test the new method on a similar subject matter. [11] To begin, I identified five well-cited academic papers dealing with critical consciousness and social justice pedagogy in STEM (shown in **Table 1**.)[6][13][10][5][14] I then took semantic embeddings (the process of turning text into numerical vectors representing concepts) of the five papers and then found the arithmetic mid-point of their semantic embedding vectors. Next, I downloaded, from the NSF website, the archives of all the abstracts for grants awarded by the NSF from the years 2020-2023.[9] I repeated the process of creating semantic embedding vectors for every award abstract in this period using Mistral's 7b LLM.[8] For each award, I identified the grant officer and the NSF division and directorate through which the awards were granted. I then computed the semantic similarity of every NSF award abstract to the five aforementioned papers (by calculating the cosine distance of each award abstract's vector embedding to the vector representing the semantic mean of the papers.) I was then able to give aggregate rankings for each NSF division and directorate (as well as individual grant officers) measuring the average semantic similarity of all of the grants given to the five papers on social justice pedagogy and critical theory in STEM.

| **Title of Paper** | **Year** | **Citation Count** |
|---|---|---|
| Social justice driven stem learning (stemj): A curricular framework for teaching stem in a social justice driven, urban, college access program. | 2017 | 26 |
| The equity ethic: Black and Latinx college students reengineering their STEM careers toward justice | 2017 | 259 |
| Lost in the Numbers: Gender Equity Discourse and Women of Color in Science, Technology, Engineering and Mathematics (STEM). | 2012 | 45 |
| Integrating critical approaches into quantitative STEM equity work | 2022 | 40 |
| Intergroup dialogue: A justice-centered pedagogy to address gender inequity in STEM | 2021 | 31 |

Table 1: Target publications to which we compare the semantic similarity of NSF award abstracts.

## 5 Results

Here, I present a few specific results from my exploratory experiment. **Table 2** and **Table 3** show the top five and bottom five NSF award abstracts (out of a total of 35,928) in terms of their semantic similarity scores to the target documents (with 1.0 being the most similar, and 0.0 being the least.) **Table 4** shows the top 5 NSF grant officers by the average semantic similarity score of the abstracts of awards they preside over to the target documents. **Table 5** shows the single lowest scoring grant officer for reference. **Table 6** shows the average scores of all 9 NSF directorates, and **Table 7** shows the average scores of the top scoring 10 (out of 38) NSF divisions.

| Score | Title of Grant Award | Award Abstract # |
|---|---|---|
| 0.8879 | Challenging Cultural Norms through Asset-focused Narratives: Examining Intersecting Stigmatized Identities from Graduate Student and Faculty Perspectives in the Natural Sciences | 2321219 |
| 0.8799 | Examining Blackness in Postsecondary STEM Education through a Multidimensional-Multiplicative Lens | 2140905 |
| 0.8792 | Planning: BPE TRACK 1: DISRUPTING RACIALIZED PRIVILEGE IN THE STEM CLASSROOM | 2234708 |
| 0.8792 | STEM Microclimates of Intersectional Inclusivity: Modeling Interrelated Programmatic Features and their Relationships to Racial Academic Disparities | 2201466 |
| 0.8767 | Conference: Privileged Logics: Interrogating Foundations and Practices in Research Ethics | 2316197 |

Table 2: Top 5 NSF award abstracts with the highest semantic similarity (cosine) score to target documents.

| Score | Title of Grant Award | Award Abstract # |
|---|---|---|
| 0.6291 | RAPID: Drivers and Improving Forecasts of Subseasonal-to-Seasonal Wildfire Potential in Hawaii | 2345296 |
| 0.6355 | ERI: A microfluidic approach for monitoring microplastics in seawater | 2347408 |
| 0.6374 | Synthesizing historical records to constrain and understand Great Sea Ice Anomalies | 2127861 |
| 0.6382 | SHF: Small: Software Testing Cognizant of Just-in-time Compilers | 2217696 |
| 0.6395 | Combinatorics and Geometry of Symmetric Group Representations | 2204415 |

Table 3: Top 5 NSF award abstracts with the lowest semantic similarity (cosine) score to target documents.

| Average Score | Grant Officer | Directorate |
|---|---|---|
| 0.8624 | [redacted] | Division Of Graduate Education (DGE) Directorate for STEM Education (EDU) |
| 0.8613 | [redacted] | Directorate for STEM Education (EDU) Division of Research on Learning in Formal and Informal Settings (DRL) |
| 0.8488 | [redacted] | Div Of Biological Infrastructure (DBI) Direct For Biological Sciences (BIO) |
| 0.8401 | [redacted] | Directorate for STEM Education (EDU) Division of Graduate Education (DGE) Graduate Research Fellowship Program |
| 0.8383 | [redacted] | Directorate for STEM Education (EDU) |

Table 4: Top 5 NSF grant officers by average semantic similarity (cosine) score to target documents.

| Average Score | Grant Officer | Directorate |
|---|---|---|
| 0.6737 | [redacted] | Directorate for Computer and Information Science and Engineering (CISE) |

Table 5: The lowest scoring NSF grant officer by average semantic similarity (cosine) score to target documents.

| Average Score | Directorate |
|---|---|
| 0.7994 | Directorate for STEM Education (EDU) |
| 0.7590 | Directorate For Social, Behavioral and Economic Science (SBE) |
| 0.7576 | Office Of The Director (O/D) |
| 0.7440 | Directorate For Mathematical and Physical Sciences (MPS) |
| 0.7424 | Directorate For Engineering (ENG) |
| 0.7395 | Directorate For Biological Sciences (BIO) |
| 0.7352 | Direct For Computer, Information Science and Engineering (CSE) |
| 0.7325 | Dir for Technology, Innovation and Partnership (TIP) |
| 0.7261 | Directorate For Geosciences (GEO) |

Table 6: NSF directorates by average semantic similarity score to target documents.

| Average Score | Division |
|---|---|
| 0.8122 | Directorate for STEM Education : Div. of Equity for Excellence in STEM |
| 0.8041 | Directorate for STEM Education : Division Of Undergraduate Education |
| 0.8021 | Directorate for STEM Education : Division Of Research On Learning |
| 0.7945 | Direct For Social, Behav & Economic Scie : SBE Off Of Multidisciplinary Activities |
| 0.7921 | Direct For Social, Behav & Economic Scie : National Center For S&E Statistics |
| 0.7838 | Directorate For Engineering : Div Of Engineering Education and Centers |
| 0.7689 | Directorate For Geosciences : Div of Res, Innovation, Synergies, and Edu |
| 0.7663 | Directorate for STEM Education : Division Of Graduate Education |
| 0.7598 | Office Of The Director : Office Of Internatl Science & Engineering |
| 0.7597 | Direct For Social, Behav & Economic Scie : Divn Of Social and Economic Sciences (GEO) |

Table 7: Top NSF divisions by average semantic similarity score to target documents.

# 6 Viability and Future Application

As can be seen from **Table 2**, this method does a reasonably good job of finding NSF awards that seem to be more oriented toward political and social engineering than to producing or advancing scientific knowledge and practices. Additionally, **Tables 4 and 7** show that we can use this tool to identify departments and individual civil servants that may warrant additional scrutiny.

The choice of target documents was somewhat arbitrary (based on a Google scholar search.) Different target documents (for which there are more developed rationales) could easily be swapped in. This method could also, easily, be adapted to other domains (The National Institute of Health, The Department of Education, and even public information from NGOs.) My previous work on NSF grants was adapted by another group and successfully applied to NIH grants.[7]

## References


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