AC 2010-1998: ARE FRENCH FRIES AND GRADES BAD FOR YOU? CONFLICTING EVIDENCE ON HOW K-12 TEACHERS SEARCH IN A K-12 DIGITAL LIBRARY

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Are French Fries and Grades Bad for You?
Conflicting Evidence on How K-12 Teachers Search
in a K-12 Engineering Digital Library

Abstract

The *TeachEngineering* digital library provides teacher-tested, standards-based engineering content for K-12 teachers to use in science and math classrooms. Since its release in 2005, *TeachEngineering* has experienced significant growth in users and contributors; data on this growth is presented. The *TeachEngineering* team—researchers at the University of Colorado at Boulder, Oregon State University, Duke University, Colorado School of Mines, and Worcester Polytechnic Institute—continues to research its search functions and user interface in order to ensure that it meets the needs of its intended users, K-12 teachers. Empirical evidence from an experimental study on the dimensions of alignment between digital K-12 lesson materials and education standards, however, contradicts that of the observed search behavior of patrons of *TeachEngineering*. Whereas the experiment convincingly shows that grade band information does not add to the teaching materials' relevance for an educational standard, observed patrons' searching patterns show ample evidence of grade band-based searches. In this paper, we offer that although grade band-based searches should perhaps be avoided because they improperly bias search results, they are such a prominent feature in the actual use of digital libraries that as designers we must support them while mitigating the risk of unfortunate search bias. As a possible solution, we suggest supporting grade-based searches as well as offering query expansion by widening the grade band.

Introduction

With NSF funding, a multi-university team of engineering researchers embarked on creating the *TeachEngineering* digital library in January 2003. Engineering educators from various universities, with advice from dozens of K-12 teachers, pooled their K-12 engineering curricula and created a unified collection—with a common look and feel—of freely-accessible teaching resources. The *TeachEngineering* digital library was launched in January 2005 as a searchable, educational standards-based repository of high-quality, classroom-tested engineering lessons and activities for use by teachers and engineering faculty to teach engineering in K-12 settings. Up to 55,000 unique users access the collection's contents monthly.

TeachEngineering (www.teachengineering.org) is a growing digital library of K-12 engineering lessons and hands-on activities. The collection's curricular materials are developed by a variety of organizations and programs, and are available free-of-charge. New institutions are continually contributing their original K-12 engineering lessons and activities, mostly NSF-funded research grantees seeking outreach and dissemination opportunities. As a result, *TeachEngineering* collection content has grown to more than 800 hands-on engineering lessons and activities.

TeachEngineering founding partner institutions are the University of Colorado at Boulder, Oregon State University, Duke University, Colorado School of Mines, and Worcester Polytechnic Institute. Beyond this team, curricular contributions from the University of South

Carolina, Vanderbilt University and Drexel University paved the way for a plethora of additional contributors. To date, K-12 engineering curricular submissions have been received from 27 different entities, of which 16 are engineering colleges with NSF GK-12 grants, and five are NSF Research Experience for Teachers (RET) programs.

The *TeachEngineering* team continues to enhance user systems and interface features, and expand the collection as it evolves to become a key STEM resource in the broader K-12 engineering community. After slow but steady usage growth in its initial years, library patronage has recently accelerated sharply (Figure 1), indicating that *TeachEngineering* has started to fulfill an important niche in K-12 education.
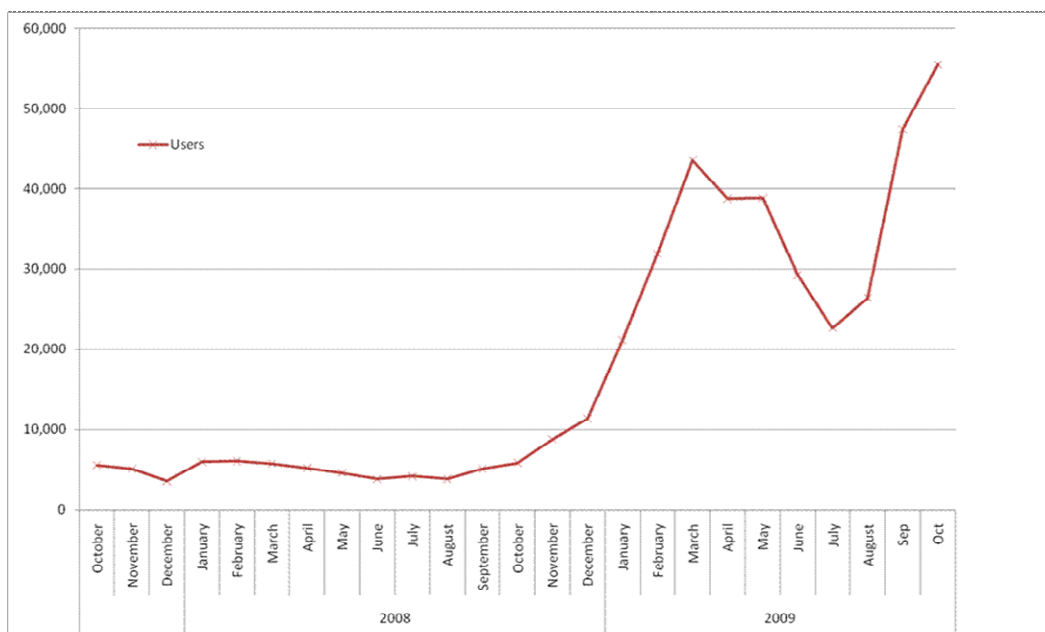

Figure 1. Trajectory of unique IP address-based *TeachEngineering* patronage.

The lessons and activities in *TeachEngineering* employ engineering as a vehicle for the integration of science and mathematics concepts through real-world, problem-solving engineering experiences. Units, lessons and activities are hands-on, inexpensive, and relevant to children's daily lives, helping science and math come alive and embarking on engineering design as a pedagogical approach. The recent, sharp increase in usage growth affirms that *TeachEngineering* also fills a niche for engineering colleges conducting K-12 work seeking a free and accessible long-term dissemination venue for their NSF-funded K-12 curricula.

Figure 2. Grade school students working on their *TeachEngineering* design project.

Development of the *TeachEngineering* collection was motivated by the following:

- A large amount of high-quality, classroom-tested curricula have been developed and dispersed over various organizations, stored in different formats and different document structures. *TeachEngineering* provides a venue to consolidate and make searchable these curricular documents.
- All learning materials in *TeachEngineering* use engineering as the vehicle to explore mathematics and science, many through an engineering design process lens. As such, *TeachEngineering* is meant to promote the use of engineering and engineering design as a means for science and mathematics learning in K-12 environments.
- *TeachEngineering* lessons and exercises are structured to fit teaching K-12 students and provide K-12 teachers with suitable and hands-on curricula at no cost beyond their effort to master and improve it. With this approach the collection developers hope to support teachers and students in all schools and districts.
- Teaching materials in *TeachEngineering* are "aligned" with the mathematics, science and technology K-12 educational standards of all US states, as well as with the standards formulated by a variety of nongovernmental national standard bodies. The intent is to make it easier for teachers to find curricula that fit the standards to which they are accountable.

One of *TeachEngineering*'s strengths is the alignment of its contents with state and national science and mathematics education standards. Original alignment is done by the curriculum developers, typically against their home state standards. However, to align the curriculum to other states' standards, *TeachEngineering* makes use of automated alignment facilities made available through the National Science Digital Library (NSDL) and developed by the Center for Natural Language Processing at Syracuse University (www.cnlp.org). Building on their NSDL-funded educational standards capabilities, in October 2008 the team released a breakthrough tool in the *TeachEngineering* digital library in which all its curricular items are near-real time aligned to the K-12 math and science educational standards of all 50 states' STEM standards.

TeachEngineering's multi-state alignment capability enables it to serve teachers from any state searching for K-12 engineering curricula that align to their state's standards. It also creates a dissemination opportunity for authors with engineering curricula who desire to map to educational standards from any state.

As most K-12 digital libraries do, *TeachEngineering* indexes its curricula by grade band. Moreover, when requesting alignment of one of its curricular items from NSDL's automatic alignment services, it uses the grade band of the curricular item to specify which parts of the national standards database must be considered for alignment. This paper examines results from two different studies of user search methods to explore how the grade level of resources is utilized by the collection's search functions to help the digital library's primary patrons—K-12 teachers—find resources for their classrooms.

Grade Bands in K-12 Digital Libraries

In recent years, an increasing number of K-12 digital libraries have appeared on the Web. Examples of these collections (**Error! Reference source not found.**) include Teachers' Domain[2,3], *TeachEngineering*[15], netTrekker[5,3], Engineering is Elementary[4,8], Curriki[16,9], the Middle School Portal[14], and the National Science Digital Library[17].

Table 1. Example K-12 curriculum digital library collections (as of November 2, 2009).

Collection	# of K-12 curricular items	Estimation method	Indexed by grade
Teachers' Domain (http://www.teachersdomain.org)	3,373	Search query to www.nsdl.org	Yes
TeachEngineering (http://www.teachengineering.org)	818	Document listing on Website	Yes
netTrekker (http://www.nettrekker.com)	300,000	Promotional video	Yes
Engineering is Elementary (http://www.mos.org/eie/)	75	Direct count on Website	Yes
Curriki (http://www.curriki.org)	32,222	Resource count displayed on home page	Yes
Middle School Portal (http://msteacher.org/)	2,562	Search query to www.nsdl.org	Yes
NSDL (http://www.nsdl.org)	79,155	Estimate by NSDL official	Yes

Each of the collections in **Error! Reference source not found.** indexes its curricular items by grade band. Hence, most of them offer one or more ways to search and browse by grade band.

At first sight, indexing teaching materials by grade band may seem an obvious requirement for digital libraries. Indeed, some of the best known and well-accepted formal schemes for documenting electronic teaching resources; *e.g.*, IEEE-LOM[6], contain specific slots for associating grade band information with a teaching resource. This association is not surprising,

partly because the ability to unequivocally code a teaching resource with a clearly-defined grade band makes for an attractive automation candidate. Also, teachers teach at a particular grade level so it makes sense that they would want to search for resources designed for that particular grade level.

When considering the context of searching for teaching materials in a digital library of learning resources, however, the role and legitimacy of grade bands become less clear. One may wonder, for instance, what it means to associate teaching content with grade bands. Would such an association mean that all content in a teaching resource is appropriate for only that grade band? Or does it mean that, on average, the material is suitable for that grade band? Similarly we might ask ourselves how likely is it that a search constrained by grade band will exclude possibly very useful learning resources or parts of learning resources, simply because in the collection those resources were associated with a different grade band? So despite its ubiquitous use to index learning materials in digital libraries, grade band might not be among the best of criteria for finding suitable curricula in those libraries.

On the other hand, one might ask how likely it is that patrons of such libraries may want or actually try to constrain their own searches with grade band information. If they do, should we, as designers of such libraries, try to dissuade them from doing this? Or should we alert them to the existence of additional resources that, although they fall outside the requested grade band, might contain useful materials? An analogy with junk and pleasure foods comes to mind; *i.e.*, if French fries are not good for us, do purveyors of such foods have a responsibility to alert their customers to the disadvantages of consuming them by putting up a notice of associated energy values? Or should they perhaps offer a complimentary supply of healthier alternatives?

What is the actual role of grade band in these digital educational collections? Do patrons of these collections search and browse by grade band and does grade band compliance add to the suitability or relevance of the teaching materials found?

We present and discuss two conflicting sets of evidence on the role of grade bands in such educational content searches. One set is derived from a recent experiment in which K-12 teachers were asked to search the *TeachEngineering* digital library of K-12 science, mathematics, and engineering curricula for materials that align with predefined educational standards[10]. The other data set is derived from the actual usage logs of the *TeachEngineering* digital library. The former data set suggests that the grade band compliance does not contribute to the relevance to found documents. The latter set, however, shows that patrons have a strong propensity to search the collection by grade band.

Grade Does Not Contribute to Relevance

Results from an experiment by Reitsma *et al.* suggest that grade band compliance does not contribute to the relevance or suitability of curricula retrieved from a K-12 educational library[10]. The experiment consisted of submitting K-12 teachers and teachers-in-training to a task in which they were given a series of educational standards—selected from several US states' K-12 science standards—and were asked to search the *TeachEngineering* library for teaching materials that "align" with those standards. Subjects scored each item found on a series of "relevance" scales

based on the relevance "clue" framework suggested by Saracevic (**Error! Reference source not found.**)[11,12,13]. Subjects were asked to express alignment between educational standard and teaching resource in two contexts; for each resource that they had found themselves and for resources found by others.

Table 2. Saracevic's relevance clues operationalized in K-12 mathematics and science classroom teaching dimensions and associated statements.

Alignment clue	Alignment dimension	Statement
Affective match	Motivation	The document contains materials that are motivational or stimulating (interesting, appealing, or engaging) for students.
Content match	Concepts	The document includes concepts, keywords, terms, and definitions from the standard.
Content match	Background	The document provides interesting and important background material related to the standard.
Object match	Grade level	The grade level of this material is appropriate for this task or else I can easily adapt the materials in this document to my grade level.
Situational match	Non-textuals	I can use a non-textual component(s); *e.g.*, figures, tables, images, videos or graphics, etc.
Situational match	Examples	I can use the real-world examples provided in the document in class.
Situational match	Hands-on	I can use one or more of the hands-on, active engineering activities.
Situational match	Attachments	I can use some of the attachments; *e.g.*, score sheets, rubrics, test questions, etc.
Situational match	References	I can use references or Internet links to relevant materials elsewhere.
Overall alignment		Overall, I consider this document relevant for this teaching assignment.
Control scale		I do have the math, science or engineering background to effectively use this document.

To test for the role of grade-appropriateness of the found teaching materials, researchers computed the difference between the grade level associated with the educational standard and the target grade level of the selected teaching resource for each scaling conducted. They then computed the correlation between that difference and both overall alignment and a teacher's self-assed ability to adjust materials to the grade level of the teaching task (**Error! Reference source not found.**). Expecting to find an inverse correlation—the greater the grade band difference the lower the relevance of the document—they found that neither of these correlations were statistically significant.

Reflecting on this result, the authors concluded that teachers partaking in this experiment essentially ignored the grade band of a teaching resource and instead carefully studied the content of the resources and decided whether or not they could use some or perhaps all of it in teaching to the assigned standard. Digital library designers strive to find ways to help their patrons find materials that will be most useful. This experiment indicates that reliance on grade band is not as useful as previously thought. The authors therefore caution K-12 digital library designers that if they associate teaching materials with narrow grade bands, teachers who search by grade band may not find materials that are very relevant to their classroom teaching tasks.

But Patrons Search the Library by Grade Band

Whereas the above-mentioned experiment provides evidence against putting too much emphasis of the grade-appropriateness of teaching materials when cataloging in digital libraries, the data in Figure 3 provide a different and possibly conflicting picture. The data show the frequencies of searches for the 25 terms most frequently submitted to a *TeachEngineering* term search. Two scores are provided for each term: the count of the term as submitted in the searches (right bars) and a count of the stemmed versions of the terms (left bars). Stemming is the process of reducing inflected or derived words to their common root form[1]. For instance, the words "electricity," "electric," and "electrical" all stem identically to their root, "electr." Similarly, the terms "engineering," "engineer," "engineers," and "engine" all reduce to their common stem, "engin." Stemming search terms increases the likelihood of counting as one term the various inflections and derivations of that term.
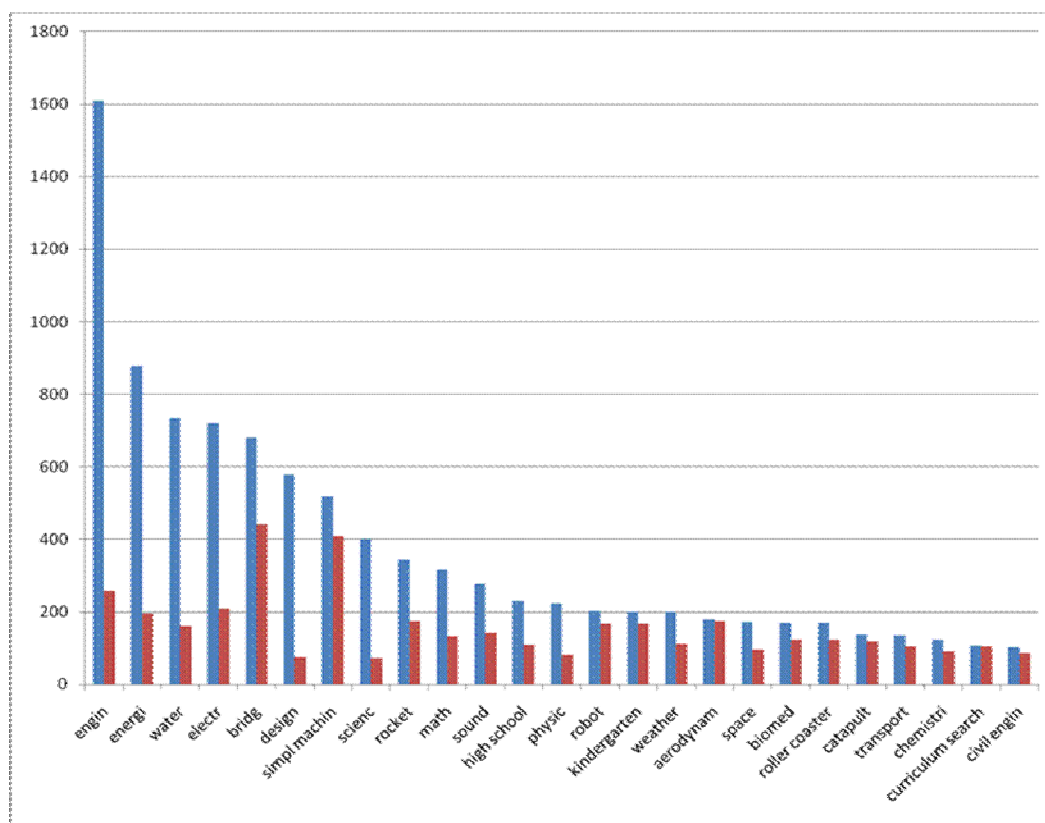

Figure 3. Stemmed (left bar) and raw (right bar) counts of the 25 most-requested search terms. (Robot and internal/project searches were excluded from these data.)

Although the search terms, as well as their rank ordering in themselves, provide food for thought on how a digital library such as *TeachEngineering* is searched by its patrons, for our current purpose we concentrate on the one single characteristic—the presence of two grade band terms "high school" and "kindergarten"—in the 15 most-submitted search terms. Although not in the top 25, other grade-related terms also scored high; *e.g.*, "middle school" at rank 45, "first grade" at rank 51 and "grade 2" and "2nd grade" at rank 69 and 71, respectively. Apparently, grade band

searches occur quite frequently, even though the experimental results discussed earlier indicated that perhaps they should not.

Are These Data Contradictory?

At first sight, the two datasets—experiment and usage logs—seem to contradict each other. Although we ourselves believe that rather than contradicting each other they show different aspects of use, the comparison of the data itself warrants some trepidation:

- Whereas the experimental data were derived in a carefully-controlled experiment, the usage log data were not. This implies two things: whereas the experimental data were collected in a context of subjects matching educational standards with curricula, the usage data contain all use contexts. And all subjects in the controlled experiment were K-12 teachers or teachers-in-training, a limitation that does not apply to the overall usage data.
- Although we have no good reason to believe so, the experiment may have biased usage into certain patterns; *i.e.*, promoted some patterns and dissuaded others.
- The usage data contain significant amounts of noise; for instance, they contain a lot of terms mistyped by patrons.

Whereas each of these threatens the validity of a comparison of the role of grade band between the two data sets, we propose that the magnitudes of the signals in both data sets are such that we must recognize that we do face a paradoxical situation; namely that when provided with a proper use context—finding curriculum for a given teaching task—teachers do not consider or even apply grade band as a relevant variable, yet usage statistics show that grade band searches are among the most prevalent of searches actually performed.

Recommendations for Grade Banding Curricula

The above considerations lead us to believe that regarding the role of grade bands associated with curriculum, we have a "French fries" situation. Like French fries, grade band-based searches for curricula do not necessarily lead to the most useful resources—the experiment bears this out—but patrons frequently use them for searching the library contents anyway. This leaves library designers with few choices, the latter two of which we recommend:

- We can simply not provide grade band-based browsing. This creates two problems: first, as **Error! Reference source not found.** shows, most, if not all, collections are indexed by grade and do in fact provide grade band-based browsing. With users accustomed to grade band-based browsing, they might consider collections that do not have this facility to be user unfriendly. Second, it exacerbates the problem indicated by Figure 3, namely that users will use other search mechanisms; *e.g.*, term-based search, as a back door to grade band-based search.
- Alternatively, we could acknowledge users' tendency to apply grade-based searches and provide them with means to conduct them, yet inform users that other, possibly useful resources that fall outside the specified grade band are available. A similar approach is applied by the search engines Google and Cuil. Google, when returning search results, offers for each result a link to "Similar" results. Cuil offers additional search categories associated with the search term.

- As a variation of the previous approach, we may again acknowledge users' tendency to apply grade-based searches and provide them with means to conduct them, yet provide easy access to ways of expanding their search. For instance, a search could allow the user to apply a grade band to the initial search. Then, after the initial search results are provided, the system could allow the user to change the grade band either increasing or decreasing it in size depending on how many results were initially returned. These types of query expansion or "slice & dice" facilities are exemplified by the travel aggregation site www.kayak.com. Aggregating the data from numerous travel sites, it lets users search and dissect a large travel data search space in many different ways, allowing virtually any combination of search criteria.

Summary and Conclusion

TeachEngineering is a rapidly-growing digital library collection of K-12 science, mathematics and engineering curricula visited by a growing number of patrons. An increasing number of programs that develop K-12 engineering curricula are choosing *TeachEngineering* as their dissemination platform as it saves them having to design and maintain a dissemination platform of their own and allows them instead to concentrate on what they do best—develop good K-12 curricula.

The growing patronage of both curriculum suppliers and consumers, however, creates an obligation on the TeachEngineering collection to provide its users with robust and desired search and collection browsing facilities. One aspect of this searching is grade band-based browsing. Evidence from experiments shows that grade bands do not significantly contribute to the relevance of teaching materials for specific teaching tasks. Actual system usage, however, shows that grade band-based searches are a desired means for accessing the collection.

Integrating these seemingly contradictory data is an important task for K-12 digital library designers. Resisting patrons' tendency to do what the experimental data tell us they should not do — but apparently want to do — might not be a productive answer to this dilemma. Instead, we might consider embracing users' tendency to search by grade band, yet help them extend and broaden their searches. The results also suggest that K-12 curriculum developers carefully assign grade bands to lessons and activities, taking into account not only the educational standards to which their curriculum is targeted but also ways and means in which it, or even parts of it, can be scaled to grades other than the target grade. Finally, we must continue to work with our K-12 teacher patrons to help them navigate digital libraries in ways that maximize their potential benefit and minimize the likelihood of inadvertently biasing their searches.

In addition to reconsidering the exposure and use of grade band information for curricula, our experimental and usage data also question our current methods for submitting curricula to automatic standard alignment tools. Recall that earlier we stated that part of such an alignment request is the specification of a grade band. After all, educational standards are grade band-specific and hence, the alignment services need a grade band to narrow the set of applicable standards. However, if, as our experimental data show, grade band does not significantly factor into the relevance of materials to those standards, we perhaps should reevaluate this approach.

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