

A search environment to make information discovery tasks valuable for children and teachers

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ABSTRACT

In this paper, we discuss our ongoing efforts focused on the development of an enhanced web search environment tailored towards 6-15 year-olds that can foster learning through the retrieval of materials that not only satisfy the information needs of users, as expressed in students' (natural language) queries, but also match with their reading abilities. YouUnderstood.me (1) recognizes the search intent of the users on-the-fly, (2) provides query suggestions that will potentially lead to the retrieval of child-related resources, (3) retrieves documents that match the readability levels of its users, and (4) offers a tracking module that keeps records of students' feedback on retrieved results, in terms of comprehension, which in turn provides information to students and educators of the change in readability levels of each individual student over time. YouUnderstood.me is an educational search environment specifically designed to help both teachers and students in dealing with personalized online searches. An initial assessment conducted on both YouUnderstood.me and well-known (child-oriented) search engines based on queries generated by K-9 students, showcases the need for this type of environment.

CCS Concepts

•Information systems → Personalization; •Social and professional topics → Children; •Applied computing → Interactive learning environments;

Keywords

Search as Learning; Children; Readability; Personalization

1. INTRODUCTION

The use of Web technologies is increasingly becoming a relevant and valuable asset for children's education [17], both because it enhances the class environment and it introduces children, from early stages of their lives, into today's in-

formation society [23]. children use the internet on a daily basis to locate materials that can help them with different academic tasks, from finding information for a class to discovering the meaning of a word. For this purpose, they often turn to search engines as the initial portal that will lead to the retrieval of materials to satisfy their information needs [17]. Unfortunately, as described by Danby [5], incorporating technology with more traditional activities into early childhood education is not a trivial task.

While the use of search engines in the classroom (and outside of it) for the enhancement of learning tasks is very common, they are not designed with children in mind, and thus a number of issues arise when they are used by this audience [11, 12]. An important barrier is showcased by the fact that Search engines tend not to be successful in understanding children's information needs, given that they are designed to satisfy interests and information needs of a general audience, without any specialization for niche users [26], such as K-12 students. This usually leads search engines to capture incorrect intent of a query written by a child, either because of the use of a long, natural language query of which the search engine can poorly detect the main content, or because a one-word query is ambiguous and the search engine give preference the results not suitable for young users [1]. Other of the most prominent issues is evidenced by the results of the survey conducted by Bilal et al. [1], from 300 retrieved results to satisfy information need of 7 graders, only 1 matched their reading level. This is an important issue since it is hard for children to process and comprehend texts with readability level that do not match their own reading abilities. Given that K-9 students as web users "differ widely in their reading proficiency and ability to understand vocabulary, depending on factors such as age, educational background, and topic interest or expertise", it is imperative not to impair their ability to carry out successful searches by finding material at an appropriate level of reading difficulty for them [4]. However, even when children retrieve resources relevant to their information needs, it is not certain that they will be able to comprehend them. As a result, students can often get discouraged when they try to read retrieved contents that are outside their comprehension levels, whether being too easy or too difficult for them to understand. As reported by Lennon and Burdick [19], reading for learning takes place when the reader comprehends 75% of a text. This represents an appropriate balance that allows the reader to positively understand the text, while also finding challenges in the reading process that will motivate him

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to improve his skills [19]. Therefore, unless the retrieved resources match the reading skills of the respective users, reading for learning, and learning as final goal, as a part of the online information seeking process cannot take place. Providing K-9 students with filtering tools they can use to seek for adequate resources they can actually understand is an imperative, since reading is an important skill in the academic environment, a competence that can be critical for students' educational opportunities and their careers [22].

As a response to issues that affect to the information seeking process when using search engines, in this paper we discuss our ongoing efforts to develop a web search environment designed to help both K-9¹ students and instructors in the process of finding adequate online materials. You-Understood.me (YUM) aims to enhance search engines, so that they can be used as a tool to facilitate learning, rather than just retrieving information, within the K-9 academic environment. The main goal of YUM is to improve the information seeking process and increase children's comprehension of retrieved materials by combining diverse functionalities oriented to overcome search engines deficiencies when dealing with children. YUM makes the information retrieval process effective and efficient by (i) taking advantage of readability formulas, a popular search engine, a search intent module [6], and query recommendation tool [7] and (ii) providing each student with a personal account which keeps track of the current readability level together with feedback on text complexity given by the student on previously retrieved results materials, which enables YUM to update the reading abilities of each student over time. With the ability to predict readability levels of students, educators can also benefit from YUM. Teachers can also benefit from an environment such as YUM, as they have access to the information related to current reading capabilities of each student and their change in time without any intrusion to students, which allows them to better adapt classes' materials and pace to the students. The novelty of YUM lays in the enhancement of search engines to create an environment that not only serves students in retrieving materials relevant to their information discovery tasks, but also ensures that the retrieved resources have appropriate reading levels. YUM ties literacy of children with information discovery tasks employed in the school. To the best of our knowledge, the proposed environment is the first one that tackles the issue of reading resource retrieval as a whole: starting from the assessment of each individual student's reading ability and ending with the retrieval of adequate materials all features and functionalities within YUM work in cooperation to improve the way in which online resources are located. Another important contribution of this work is that YUM builds a bridge to establish a direct relationship between teachers and students, where teachers can follow the progress in readability levels among the students and further foster the learning process.

2. RELATED WORK

The importance of personalized search when using search engines can be quantified by the number of studies that have targeted this issue [4, 9, 16, 26]. Wang et al. [26] introduce

¹K-9 refers to the publicly-supported school grades prior to high school sophomores in the education systems from the United States of America, Canada and other countries.

a ranking model adaptation framework that facilitates the retrieval of personalized resources when conducting online searches, whereas Eickhoff and Collins-Thompson [9] discuss the results of examining large-scale query logs to further enhance the personalization task. Similar to our claims, the authors in [9, 26] argue for the need to personalize search results to satisfy diverse users' needs and preferences. However, while the authors in [9, 26] focus the personalization strategy on parameters such as authority of web pages or atypical search sessions, respectively, we initially focus on parameters that can aid the learning acquisition process, i.e., readability levels of retrieved results. Personalization based on readability has also been explored by a number of researchers [4, 16]. The most prominent discussions are the ones by Collins et al. [4] who demonstrate, based on the results of an extensive query-log analysis, that readability is a valuable signal for relevance of retrieved resources, and the study presented in [16], in which the authors highlight the need for suitable readability levels on resources retrieved as a result of queries on complex topic formulated by non-experts. We agree with their assessment on the importance of readability in personalizing web searches, which is why YUM is designed to present its users with resources they can read and understand to enhance the process of information seeking tasks for learning purposes.

Our efforts to create an educational search environment with a focus on solving issues K-9 students have while performing online searches to perform information related tasks are further encouraged by the analyses and conclusions reported by Huumerdeman and Kamps[14], who argue for the need to connect literacy and search engines.

The closes environment to the one we propose is the one described in [25] Their proposed application includes a new GUI for web search purposes with a number of filters that, among the others, include the grade level of the user. YUM is build upon Google search engine, given that young users prefer using it while performing information seeking process [1]. As described in [3], K-12 students' have different readability levels even if they belong to the same grade, therefore YUM does not use grade level as a desired readability level of its users.

To the best of our knowledge, YUM is the only education-oriented environment that considers readability levels, as well as queries that potentially lead to the retrieval of child-targeted resources to aid K-12 students in completing successful information seeking process within the classroom setting.

3. YOUUNDESTOOD.ME

YUM is an online environment built around a search engine, which aims to make the search process valuable for children. As opposed to similar environments[25], YUM is not meant to be treated as a new, child-oriented search engine, since studies [1] show that children tend to prefer popular search engines, such as Google, to perform their online information-seeking tasks. Instead, YUM acts as an intermediate layer between the child and an existing search engine, in order to facilitate the interaction between the two of them. For doing so, YUM puts into practice strategies oriented to address issues children face when using popular search engines, as well as strategies that can enhance the search experience to foster learning. A description of the mentioned strategies is provided below.

3.1 Search intent

Children are not always able to formulate succinct queries [2]. Studies show that they tend to write natural language queries, instead of short, keyword-based ones that search engines usually expect [8]. Unfortunately, the longer the query, the less likely it is for a search engine to retrieve relevant results in response to it, making children unable to successfully complete information seeking tasks [8]. In addition, children also tend to misspell words, but not necessarily in the same fashion as average users. For example, children commonly repeat letters in a word to emphasize it, such as in "faaaaast", which can cause search engines to misunderstand the intended meaning of the word. In order to best satisfy children needs YUM leverage our previous research work QuIK [6], a search intent module designed specifically for children. QuIK addresses common patterns in each query Q written by a child including, but not limited to, diminutives, emphasis, children trendy terms or children specific misspellings, and transforms Q into a new keyword-based query that captures the information expressed by the child in a way that can be more easily comprehended by search engines.

3.2 Query suggestion

Even if the search intent module identifies the most likely user intent for each query, users have different interests and information needs, which is why when dealing with ambiguous queries, it is only each specific user who knows the purpose of his search. With this in mind, YUM takes advantage of ReQuIK [7], a query recommender that is specifically tailored to children, and provides alternatives for the initial query, that the user can select, to better inform the search process. ReQuIK is a multi-criteria recommendation system based on traits commonly associated with children which suggests queries that (i) are associated with children topics, (ii) lead to the retrieval of resources with levels of readability matching those of the K-12 audience, and (iii) are diverse enough to capture the different topics children can be interested in.

3.3 Filtering by readability

Even when the search engine has understood the intent of a child query and retrieves results that match the information needs expressed by the corresponding users, the suitability of the retrieved resources is still not assured. K-9 students tend to find difficult to understand documents containing complex or technical vocabulary. For example, in the case where a child is looking for information about chemistry, retrieving a scientific publication would not be adequate, while retrieving information from an elementary chemistry book would. If the retrieved documents are too complex, children may not succeed in completing their information discovery tasks. In order to avoid this situation, YUM incorporates as part of its environment a filtering strategy based on readability levels. This strategy ensures that the retrieved documents will match, to a degree, the reading ability of each individual user. YUM allows users to go through a one-time process where they can select their grade level. This grade level is originally used as a target to eliminate retrieved resources that are not within half a grade level above or below the grade of the corresponding student. For estimating the readability of retrieved resources, YUM uses the Flesh-Kincaid [10] (see Equation 1) readabil-

ity formula. We initially selected this formula given that it is widely used for measuring the readability levels or complexity of texts among educators nationwide and is considered as a standard by institutions [15] to measure readability levels.

$$FK = 206.835 - 1.015 \left(\frac{\text{total words}}{\text{total sentences}} \right) - 84.6 \left(\frac{\text{total syllables}}{\text{total words}} \right) \quad (1)$$

3.4 Tracking

K-9 students have diverse reading abilities. In fact, even in same grade class, readability skills can differ [3]. Furthermore, the reading skills of each individual progressively improve over time [24] and as stated by Collins et al. [4], users' reading proficiency is estimated based on both, current and past searching process. Consequently, the one-size-fits-all strategy is not applicable for conducting successful information-seeking tasks that lead to the retrieval of resources individual users can read and understand. Instead, YUM employs an adaptive strategy that allows its users to provide optional feedback specifying whether the resource was too "Easy", "OK" or "Too complex" for them. This feedback is used to determine and update the reading skills of each user so that the system can retrieve documents adequate to their current level of readability. The problem of predicting the current readability level of each student can be treated as a constraint satisfaction problem, where each feedback provided by a student generates a new constraint that needs to be satisfied by the readability of the student. For example, a student s giving a feedback of "Too complex" to a document of readability level 5 would generate the constraint $r_s < 5$ stating that s ' readability should be lower than 5. As showed in Equation 2, the predicted readability r for s is the one that maximizes the amount of constraints satisfied. The equation also considers the time when each constraint was created, giving more importance to constraints that were created more recently and discarding the ones created outside current academic year. For doing so, $f(c_i)$ is a function that starts at value 9 for a new constraint c_i and decreases by 1 for each month since the corresponding feedback was provided until 0. We selected 9 as the number of months to consider as this represents the average length of an academic year.

$$\arg \min_r \sum_{c_i \in C} \begin{cases} f(c_i) & \text{if } r \text{ satisfies } c_i \\ 0 & \text{otherwise} \end{cases} \quad (2)$$

where $r \in R = \{0, 0.5, \dots, 8.5, 9\}$ is the predicted readability value for the student and C is the set of constraints created based on the feedback provided on retrieved resources by a user s .

At the beginning of each academic year or when the first time the environment is used, the constraints of every student's accounts are initialized with two constraints based on the grade level of the student or the readability level prediction on the system for the previous academic year. Those 2 initial constraints represent one grade of deviation from the current grade of the student: $r_s < g_s + 0.5$ and $r_s > g_s - 0.5$ where g_s represents the current grade of student s . These constraints give a starting point to YUM, that will eventually be better adjusted when the student start using the environment.

4. YUM FOR TEACHERS

Teachers can also benefit from using YUM within the class environment. Work setting standards have changed from a vertical structure, where only the top individuals of the pyramid had to think critically and the lower parts just followed directions, to an horizontal structure, where each individual is expected to collaborate with others and solve important problems using identification, searching, synthesizing, and communication skills [20]. Given this change, education plans oriented to meet the new requirements of the current industry, such as the Common Core State Standards Initiative (CCSS), have been developed. CCSS requests educators to make an emphasis on higher level thinking during reading and writing and focus on the acquisition of skills such as research and comprehension using digital tools, including search engines[20]. Furthermore, educational studies [18] showcase the benefit of in-class exercises such as exploratory talks, where students are asked to solve a problem in groups discussing information found on resources obtained using a search engine. Unfortunately, teachers might not be able to propose such a task to their students and lead critical discussions, if students have problems using search engines, whether that be struggling to find the right queries or not being able to understand the retrieved documents due to their complexity. YUM can help teachers overcome those issues so that they can instead focus on the discussion, rather than on the manner in which students should formulate queries or the type of results they access. Furthermore, YUM can serve as a monitoring tool that allows teachers to check students' progress, based on the resources they have retrieved and their provided feedback in terms of complexity. We believe that YUM can not only facilitate learning when children use it for their information discovery assignments at home, but it will also help teachers within the classroom environment, by addressing the challenge of seamlessly integrating technology to perform everyday classroom activities [5, 18].

5. INITIAL STUDY

As previously stated, YUM is more than a search engine for children, instead, it is an enhanced web environment that incorporates features oriented towards facilitating and fostering learning as a result of conducting information seeking tasks online. Therefore, in this initial assessment we focus on demonstrating the need and effectiveness for this environment. We also consider in our initial assessment a number of popular search engines oriented to children: Kiddle.co, KidRex.org, SafeSearchKids.com and Gogoolingans.com. Given that, studies show that children tend to prefer popular search engines, such as Google to perform their information-seeking tasks[1], even if these engines target a more general audience, we also include Google in our analysis.

Due to the lack of benchmark datasets available for evaluating search-related tools focused on young users, we collected our own sample of queries written by children, which we denoted ChildrenQS (Children query sample). This sample includes 300 unique queries written by 50 children between the ages of 6 and 15. In creating ChildrenQS, we asked various K-9 teachers in the Idaho (USA) area to propose their students an information discovery task for which the students had to create queries. We submitted 100 queries (randomly-sampled from ChildrenQS) to each of the search

engines considered in this study and examined the respective retrieved resources as well as the challenges children need to overcome when using these search engines. We discuss below details pertaining to each of the aspects considered for our assessment. Furthermore, an overview of our initial findings are presented in Table 5.

Inability to retrieve resources. Children are known to struggle when composing queries, often creating queries that are too long and in a natural language form, as opposed to succinct keyword queries search engines usually expect [Dru09]. Based on our assessment using queries in ChildrenQS, we observed that for XX% of the queries, (child-oriented) search engines considered in this analysis did not retrieve any results, as opposed to the X% for which YUM could not retrieve resources. In a more in-depth manual analysis we discovered that YY% of the queries that only YUM could handle were queries containing more than YY terms, demonstrating the validity of using a children oriented search intent strategy.

Readability. The readability level of resources retrieved in response to a child query is also a relevant aspect to explore to quantify the success of a search from a reading for learning perspective, since, as previously stated, retrieving too complex documents can lead a child to frustration due to their inability to understand what has been retrieved. We computed the average readability level of the top-N results retrieved for 100 queries in ChildrenQS. Given that "children are known to systematically go through retrieved resources and rarely judge retrieved information sources" [12] we computed the readability scores reported in Table 5 based on the Top-3 documents retrieved in response to each query. For measuring the readability level of the retrieved resources, we selected the Flesch [10] readability formula, as it is considered a standard nationwide [13]. Recall that YUM filters our retrieved resources that do have a complexity level within +/- 0.5 deviation from the reading level of each user, assuring that retrieved resources can be comprehended by its users. Therefore, we only computed the average readability levels of resources retrieved in response to queries posted on (child-oriented) search engines considered in this analysis. As shown in Table 5, the readability levels of resources retrieved by child-oriented search engines are generally above 10, and even one of the search engines (SafeSearchKids) retrieved resources that average 15.6, in terms of readability levels. Google, being the most used search engine achieved a score of 12.4 in terms of average readability in retrieved results. This demonstrated that even if most of the tested search engines use Google safe search for filtering results, not containing mature content does not mean that the documents are adequate for children in terms of complexity.

General experience. The quality of a search engine is not only determined by its retrieved results, instead the general search environment is also important [11]. Therefore, in as part of our qualitative assessment we expand on the analysis framework presented in [11]. We observed that the presence of ads was recurrent among the search engines considered in this study. These ads were usually indistinguishable from relevant retrieved resources, which can be confusing, and more importantly, advertised products unsuitable for children. For example, we found ads that referred to drug re-

	YUM	Google	Kiddle	KidRex	Safe Search Kids	Gogooligans
Inability to retrieve results						42% (Cannot handle questions)
Average readability(Flesh)	Chosen by the user	12.4	12.8	10.6	15.6	11.6
Non adequate contents	None	Ads not for children	Ads related to submitted query	None	Non- filtered ads	Ads filtered for children
Mobile friendly	Yes	Yes	Yes	No	Poor adaptation	No
Query suggestions	Yes	Yes, but for general audience	No	No	No	Yes

Table 1: Comparison of search environments

habilitation programs or anti-aging products among results retrieved by SafeSearchKids in response to queries such as “frozen characters”. We also noticed that platform adaptability was an issue for some of the search engines, since they showed poor support for small screens, such as the ones from phones or tablets, making it hard for a child to use the same system in all platforms. This supposes a significant drawback, given that 71% of children usually access the internet through a tablet [21]. Finally, most of the search engines oriented to children showed no or poor support for helping children improve their queries. 2 suggest query reformulations while typing them, however, these suggestions are not tailored to children and do not go beyond dictionary based auto completion. YUM currently meets the three criteria described, by excluding ads, being adaptable to smaller screens and supporting children to improve their queries by providing suggestions or using the most likely search intent, if no suggestion is selected.

6. CONCLUSIONS

In this paper we presented YUM, an online environment that addresses issues children face when using popular search engines to conduct information seeking tasks. YUM can facilitate the learning that can occur while reading resources that are retrieved as a result of an online child-initiated search. As part of our ongoing research efforts, we leverage the use of popular search engines, search intent and query suggestion modules we have already developed, a readability-based filtering strategy and a novel tracking strategy, to enhance the search-for-learning tasks conducted online and informing teachers of the progress of their students, in term of reading and comprehension. As part of our ongoing work, we conducted an initial assessment using queries written by children in K-9 grades and demonstrated the need for environments such as YUM. We plan to extend the functionalities and usefulness of YUM by implementing a number of enhancements: we are aware that the Flesch formula currently used in YUM, may not be precise enough. Therefore, we will build our own readability assessment tool which will go beyond counting terms and syllables, and instead will consider web-page specific metadata as well as more in-depth language information, such as syntax and semantics. We would also like to explore different filtering strategies based on web page authority and maturity of the content retrieved, so that retrieved resources are more suitable to children. Finally, we would like to conduct a more in-depth study to better understand, quantify and showcase the correlation between learning and information discovery tasks conducted using enhanced web search environments. Since the developmental stages and information needs of children K-9 are broad, we will conduct these studies based on more

specific age ranges, such as 6-8 and 9-12.

In the future, we envision YUM as an environment a child could use independently of the information discovery task pursued. For doing so, we plan to extend the range of the documents YUM can retrieve, including searches in local catalogs such as school libraries or dictionaries. We also aim to add support for multiple languages so that children that know different languages can use their YUM account both at home and at school. Finally, we would also like to explore and incorporate new ways of collaborative searching between various students and the teacher, which could further enhance the learning while searching.

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