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ABSTRACT

Children use popular web search tools, which are generally designed for adult users. Because children have different developmental needs than adults, these tools may not always adequately support their search for information. Moreover, even though search tools offer support to help in query formulation, these too are aimed at adults and may hinder children rather than help them. This calls for the examination of existing technologies in this area, to better understand what remains to be done when it comes to facilitating query-formulation tasks for young users. In this paper, we investigate interaction elements of query formulation–including query suggestion algorithms–for children. The primary goals of our research efforts are to: (i) examine existing plug-ins and interfaces that explicitly aid children's query formulation; (ii) investigate children's interactions with suggestions offered by a general-purpose query suggestion strategy vs. a counterpart designed with children in mind; and (iii) identify, via participatory design sessions, their preferences when it comes to tools / strategies that can help children find information and guide them through the query formulation process. Our analysis shows that existing tools do not meet children's needs and expectations; the outcomes of our work can guide researchers and developers as they implement query formulation strategies for children.

CCS CONCEPTS

• Information systems → Recommender systems; **• Human-centered computing → Human computer interaction(HCI)**.

KEYWORDS

Query formulation; children; query suggestions; participatory design

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1 INTRODUCTION

Children regularly turn to search tools as a starting point in their quest for online resources: from videos, games and story books to educational materials [18, 55, 63]. To initiate the search process, children must formulate effective queries. Unfortunately, children's limited vocabulary and difficulty identifying the right keywords to succinctly express their information needs, make this a challenging task [35, 69, 71].

A traditional strategy to ease the query formulation process is through the guidance of experienced individuals or peers [38]. A technology-based alternative involves the use of built-in functionality that can assist children in creating queries. While this has received attention from developers and researchers [22, 23, 33], a standard of practice in this area is yet to emerge. To our knowledge, there is no de-facto query formulation strategy favored by children. To better understand how existing strategies address children's query formulation problems and the varying ways to help children formulate queries when using search tools, we build upon the results presented by the authors in [16] and ask these research questions:

- In what ways can children get help when formulating queries?
- Are there query formulation strategies tailored specifically for children?
- Do children favor assistance targeted specifically for them?
- What type of help do children expect for query formulation?

Indeed there are several strategies that offer assistance to users, including children, when formulating queries. Common methods used are *query expansion* and *query suggestions*. Query expansion techniques involve generating new queries by substituting or adding new words or phrases to the original query written by a user in a search box [17, 30]. Query suggestions (QS) are words that pop-up underneath a search text entry box that users can select to help them formulate their query. The aim of generating QS is to predict a user's search intent, which better reflects the user's information need [26]. QS are available on popular search tools, such as Google and Bing. Their suggestions, however, are generally geared towards the assumed primary user: an adult [34].

An initial inspection revealed a more limited number of algorithms and tools that explicitly target children, as compared to general users. Furthermore, assessments of these algorithms and tools are rarely, if at all, based on direct feedback from children, making directions of what children need to formulate effective queries inconclusive. To shed light into the discussion of the necessity for further query assistance for young populations, in this paper we: (i) identify and examine how existing search tools assist children when formulating queries, (ii) examine children's interactions and perceived satisfaction with various QS, and (iii) identify children's preferences when it comes to tools / strategies that can help them create proper queries.

In answering the aforementioned open questions and to contextualize our contributions, we first present related literature to children's search and explore existing algorithmic efforts focused on query suggestion strategies available in web tools designed for children; we discuss their limitations, as well as the issues they are trying to solve when it comes to improving information discovery tasks through proper query formulation [46]. We then present the results of a pilot study of children using a query suggestion strategy that specifically targets them, as well as one that is designed for a general audience (i.e., Bing). Lastly, we discuss the outcomes of four participatory design sessions–specifically using the Cooperative Inquiry method [37, 45]–which revealed needs and preferences when it comes to the query formulation assistance children expect from a search tool designed for them. The results of these studies translate into several lessons learned that can benefit researchers and practitioners who design and develop search tools for children.

2 RELATED LITERATURE

We discuss below how search environments for children, in varying degrees, deal with query formulation assistance. We also present literature pertaining to existing strategies for generating QS (both for general and young audiences), which is the focus of our work.

2.1 Search Tools for Children

A number of researchers have developed search environments for children that offer query formulation assistance [40, 41]. Gossen [40] outlines a number of these interfaces and search tools; some of which are now defunct [1] and others handle information in languages beyond English [40].

Recently developed and currently accessible search environments, e.g., Kidrex [50], Kiddle [49] and Kidzsearch [52], are tailored specifically for children. While detailed discussions on existing environments have been addressed in the literature [18, 40], it is worth noting that they are designed to provide children with results that satisfy both their child-specific general-purpose and educational information needs. Efforts on these environments are focused on curating resources or on filtering resources retrieved in response to a child-formulated query, as opposed to query formulation. A number of these environments either do not offer QS or do not provide suggestions for certain query types, i.e., misspelled query terms and long natural language queries. This is a concern, since children are known to often misspell their queries and formulate long natural language queries [33]. Hence, it would be beneficial for query suggestion modules to offer suggestions irrespective of how children express their information need through their queries.

2.2 Query Suggestion Strategies for Diverse Audiences

Literature discussing algorithms for generating QS is prolific [21, 27, 48, 57, 67, 74]. Most existing methods take advantage of users' click-through data from query logs in order to generate QS [27, 39]. Unfortunately, since the majority of the users are not children, the suggestions generated using query logs are more likely to target the interests of a general population, therefore making non-traditional users like children under-served in terms of addressing their specific information needs. Another issue with strategies that rely on query logs is that required click-through data explicitly generated by children is seldom available, due to privacy rules. In the absence of query logs, other methodologies exploit phrases extracted from indexed resources [21], or domain-specific document corpora [56], which are scarce when it comes to child-oriented content; or are based on probability models that consider knowledge bases or community question answering sites, which can result in suggestions that do not reflect content or vocabulary appealing to children [31].

To address some of the aforementioned limitations, researchers have dedicated efforts to developing algorithms for QS that explicitly target children [35, 36, 69, 72, 73]. The research conducted by Torres et al. [35, 69] and Eickoff et al. [36] focus on expanding a child's written query by taking advantage of tags used to describe child-friendly documents. These approaches favor suggestions that are more focused on content for children. Vidinli et al. [72] focus on offering QS that would lead to the retrieval of educationally-relevant web resources. The aforementioned strategies [35, 69, 72], however, rely on extracting child-related information from existing query logs. This approach may be problematic, as some search patterns are common among adults and children, hence making this unreliable for explicitly identifying information for children from unlabeled query logs.

The authors in [59, 65, 73] introduce strategies that capture patterns from child-friendly resources, as opposed to using query logs. Due to the fact that children may not have the right vocabulary to write queries that would lead them to the right set of resources, Shaikh et al. [65] create phrases from web resources that include texts written by children. Madrazo et al. [59] introduce ReQuIK, a strategy that interprets the search intent of a query and examines candidate suggestions from multiple perspectives to infer if each suggestion is child-related. ReQuIK uses a wide and deep learning algorithm that considers children vocabulary, phrases and named entities popular among young audiences, as well as content written for and by children. In doing so, ReQuIK can generate suggestions that are child-friendly and have the potential to lead to resources with text complexity levels compatible with those expected for children in the first to seventh grades.

The strategies mentioned above, which offer QS in the absence of query logs, are able to capture child-oriented vocabulary and popular culture terms, as they explicitly focus on generating suggestions from texts written for or by children. However, these strategies do not include data that would normally be available in query logs, such as recent information that people are searching for on the web.

Regardless of the approach, it is difficult to identify what a good suggestion is, unless one obtains direct feedback from children. Doing so is difficult, as children are a protected population, leading to limited literature reports. In this paper, in addition to a survey analysis of current tools and strategies, we present findings based on children's direct feedback on query suggestion tools, and lessons learned from participatory design sessions leading to guidelines for appropriate query suggestion approaches for children. These insights are imperative to the design and development of technology that can lead to the improvement of search discovery tasks.

3 SURVEY OF TOOLS THAT OFFER QUERY FORMULATION ASSISTANCE FOR CHILDREN

In this section, we present our analysis of how existing child-oriented and popular search tools (defined below) assist children in formulating queries. We offer a summary in Table 1.

A **search engine** is an information retrieval system that retrieves a ranked list of documents from multiple web sources in response to a user's query [29]. Research shows that young children turn to search engines daily as their first "port of call for knowledge" [18, 63]. Children also rely on browsing websites and plug-ins. In our paper, **browsing websites** are tools that allow a user to only search for information within a specific domain (e.g., class subjects or materials on a school website). Unlike stand-alone tools like search engines and browsing websites, **plug-ins** are software components that can be added to an existing software program, e.g., a web browser, in order to carry out specific functions such as assisting with spelling or filtering inappropriate content.

3.1 Interfaces

We limit our analysis to tools that are functional and work for English speaking users, as we are building on prior work that also focused on English. We start from those surveyed by Gossen [40], but also include other search interfaces[1] which we identified by searching using the query "children search tools and websites" on Google.

Among the search interfaces examined, we included search engines designed exclusively for children, e.g., Kidrex [50], Kiddle [49] and Kidzsearch [52], as well as children's popular browsing websites, such as IXL [7], Khan Academy [8], and International Children Digital Library [6]. We also considered popular search engines, e.g., Google [4] and Bing [2], as existing research shows that these are preferred and commonly used by children to perform search tasks [24, 38]. Given our interest in investigating the form of assistance offered to children while they create queries, we analyzed these search interfaces from multiple perspectives: (i) spelling correction (ii) type of assistance, and (iii) query suggestions.

3.1.1 Spelling Correction. We explored the functionality offered by the search interfaces in handling misspelled queries, given that children often write queries that contain spelling errors. We specifically focused on identifying if the written query terms were corrected while a query was being formulated or after the search had been triggered. This distinction is important as relevant results are only retrieved if the right information is being used to initiate the search. For instance, if a child intended to search for "*apple*" but instead misspells the query term as "*ample*", the search tool will retrieve results based on the written (not the intended) term, which may be irrelevant to the child.

We found that Kidrex [50] and Sweet Search [60] do not provide spell correction while the user is typing a query, but instead corrected queries after the search was triggered. For example, Sweet Search directly retrieves resources for a corrected spelling of the query "*tomas and freinds*" (a TV show for kids, see Figure 1) but does not specifically identify the misspellings in the query itself. Furthermore, when a misspelled query is used to initiate a search, some tools display feedback under the search box, showcasing the corrected query and the query that the user initially typed.

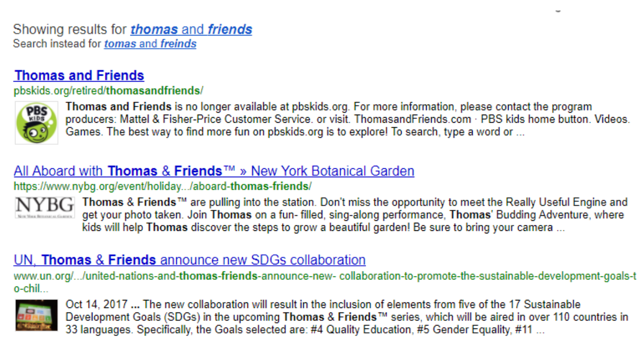

Figure 1: An example of queries being only corrected at the time of search, using Sweet Search.

Some interfaces do not offer spell correction or retrieve any resources in response to a misspelled query. For instance, for the query term "*dinasaur*" (which should be "*dinosaur*"), KidCyber [66] does not return any results; shown in Figure 2.

Figure 2: An example that showcases when no result was retrieved for a misspelled query, using KidCyber.

Neither retrieving any results when children misspell their queries nor offering assistance to correct the misspelled query terms are limitations, as children do not always have the right vocabulary to express their information need. This may make them frustrated and less motivated to continue to search.

3.1.2 Type of Assistance. We investigated the type of query assistance offered by the interfaces, as it is a challenge for children to identify the right keywords [65] or combine them using boolean terms (AND, OR, and NOT) when constructing queries [61]. The

[1]We categorize search engines and browsing websites as interfaces.

Type	Tool Name	Domain	Spelling Correction	Type of Assistance	Query Suggestion
SE	Bing [2]	Web	Yes	No	Yes
SE	Dib Dab Doo [32]	Web	No	Guided QF	No
SE	Dog Pile [14]	Web	No	No	Yes
SE	Google [4]	Web	Yes	No	Yes
SE	Infotopia [20]	Web	Yes	Guided QF	No
SE	IPL2 [70]	Web	No	Guided QF	No
SE	Kiddle [49]	Web	Yes	No	No
SE	KidRex [50]	Web	Yes	No	No
SE	Kid's Search [9]	Web	Yes	Guided QF	No
SE	KidzSearch [52]	Web	Yes	No	Yes
SE	Safe Search Kids [11]	Web	Yes	No	No
SE	Sweet Search [60]	Web	Yes	No	No
Website	Britannica Kids [13]	Education	No	Guided QF	No
Website	Cyber Sleuth Kids [51]	Education	No	Guided QF	No
Website	Dk Find Out! [54]	Education	No	Guided QF	No
Website	Fact Monster [64]	Education	Yes	Guided QF	No
Website	Fun Brain [15]	Education	No	Guided QF	No
Website	International Children's Digital Library [6]	Books	No	Boolean QF	No
Website	IXL [7]	Education	Yes	Guided QF	Yes
Website	Khan Academy [8]	Education	Yes	Guided QF	Yes
Website	Kidcyber [66]	Education	No	Guided QF	Yes
Website	PBS Learning Media [10]	Education	No	Boolean QF	No
Plug-in	Co:Writer Universal [3]	Web	Yes	No	No
Plug-in	Google Search Filter [5]	Web	Yes	No	Yes
Plug-in	ReQuIK[59]	Web	Yes	No	Yes
Plug-in	Search Manager [12]	Web	Yes	No	Yes

Table 1: Sampled search tools for children, highlighting query formulation functionality. SE and QF refer to "Search engine" and "Query Formulation".

few interfaces that provided assistance did this in the form of a boolean type search or by offering guidance, i.e., categories, as children formulate queries.

Some interfaces provided click-able components, e.g., pictorial buttons, which children could use in order to construct a **boolean** query. For instance, as a child navigates PBS Learning Media [10], he is presented with click-able categories such as Subject, Resource Type, Grade level, and Language. If he would like to search about shapes, he can type "*shapes*" and then select "*mathematics*" for the subject and "*1*" for the grade level, which forms the query "*shapes + mathematics + 1*" .

The International Children's Digital Library [6] functions similarly to PBS media. This website offers boolean query formulation assistance when kids search for books to read. Several categories are displayed, such as cover color, book length, age, and character type, and a child can initiate the search by either selecting a category or by typing a keyword. One limitation of boolean query formulation assistance is that if a child decides to initiate the search process using a keyword, then the keyword must be spelled correctly to proceed with the search.

Some interfaces offered **guidance** when formulating queries so that a child could search for information without necessarily typing a query. Interfaces that offer this functionality emulate the query formulation process by allowing children to select resources grouped under a subject hierarchy on educational interfaces or click on a keyword that they intend to search for on web-based interfaces. Most browsing websites offered this form of assistance (e.g., Fact Monster and Kids Cyber). For instance, on Fact Monster [64], if a user selects the category "Science", several subjects , e.g., Biology, Earth Science, and Physics, are offered. If the option "Biology" is selected, content related to biology for kids is displayed.

We found this type of query assistance to be especially useful for children that may not be certain as to what to write as their query, but have ideas on subjects or keyword phrases that they could use to construct the query. However, the information retrieved for a child's query may only be limited to the resources provided by the search tool and not from the entire web.

3.1.3 Query Suggestion. We examined the availability of QS in search interfaces, essential for providing a child with: (i) other queries that are similar to a typed query, (ii) complete queries to the child's incomplete query term, and (iii) other queries that address different topics that could be of interest to the child. We found that most tools that are designed explicitly for children did not offer this functionality–KidzSearch [52] and Dog Pile [14] were the only child-oriented engines that provided QS. We observed that IXL [7] QS are grouped by subject areas and suitable grade-level.

3.2 Plug-ins

Driven by the perspectives discussed in the **Interfaces** section, we also examine plug-ins that can enhance the functionality of search interfaces by assisting children in formulating queries. For our analysis, we identified plug-ins available from the Chrome web store by searching for "children web search plug-ins". Note that we only examined plug-ins from the Chrome store, as we could not find other plug-ins that could potentially aid children's search when browsing other web stores.

3.2.1 Spelling Correction. We observed that all the examined plug-ins corrected misspelled queries as they were being formulated. For example, when typing "*leggos*" (a children's toy brand company) on Search Manager or Co: Writer universal, the right spelling of the query term is displayed before a user triggers the search.

3.2.2 Type of Assistance. None of the plug-ins offered any type of query formulation assistance. Search Manager only helps a user select a search engine, e.g., Bing and Google, to search with. Google Search Filter assists users to search with keywords on a specific website. This plug-in also enables a user to select the file extension of the web resource to be retrieved for their queries.

3.2.3 Query Suggestions. Plug-ins that provided QS were Google Search Filter [5], ReQuIK [59], and Search Manager [12]. Other than ReQuIK, the others do not offer suggestions on their own, but alter the suggestions offered from general-purpose search engines. For instance, the Google Search Filter provides a parental control function that disregards QS that can potentially lead to the retrieval of inappropriate resources. On the other hand, the Google Search Manager allows children to select their preferred search engines, which in turn changes the suggestions that would be provided for a given query.

4 OBSERVING CHILDREN USING QUERY SUGGESTIONS

Over the past few years, researchers have examined search tools and discussed their strengths and limitations when it comes to helping children complete information discovery tasks [33, 40]. In the previous section, we focused our examination and discussion to how these tools aid in the first step required for completing successful searches: query formulation. The analysis, however, does not take into account the direct perspective of the target audience: children. With that in mind, we performed a pilot study to observe differences between using different query suggestion strategies: one targeted for general users and one customized for children. For the general purpose QS we utilized Bing because it is a popular search engine [68] and it has a readily available suggestion API. We used ReQuIK[2] [59] as the customized suggestion tool for children, as the authors made available an API for research purposes. As mentioned in the Related Literature section, unlike its counterparts ReQuIK analyzes candidate suggestions from multiple perspectives in order to identify those that better reflect children's vocabulary and topics of interest.

4.1 Query Suggestion Method

We obtained query and query interaction logs from a previous work-in-progress study that reported on survey data and processes [16] from a pilot study. The pilot study was conducted over two 40-minute search sessions with 8 children (5 girls, and 3 boys) ages 6-10. Each session consisted of a different set of search prompts, where all children received the same search prompts approximately every few minutes. (See Table 2 for example query prompts and child-entered queries.) The children used a uniform generic interface (see Figure 3, top) on a desktop computer for entering the search queries, and were shown in random order the top three suggestions from Bing and ReQuIK (see Figure 3, bottom). Each session's interface and process was slightly different as described as follows:

- **Query Suggestion Session 1 (QS1):** QSs popped up and children indicated which suggestions they liked–or rather which they thought matched their query intent based on the query they started to enter. Half of the children received different interfaces first: in group **QS1a** suggestions were triggered after a space was entered, in **QS1b** suggestions were triggered after 6-20 characters (chosen randomly). Neither group received search results, they just indicated which QSs they liked.
- **Query Suggestion Session 2 (QS2):** After 10 seconds, QSs would pop-up. Children could change the query and could get search results.

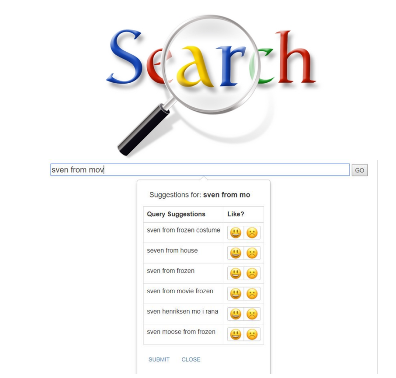

Figure 3: Initial generic search interface.

4.2 Query Suggestion Preference Analysis by Query Type

The pilot study resulted in a total of 235 queries which triggered the display of 1409 QSs, from which children gave explicit feedback

[2]We briefly introduced ReQuIK in the Related Literature section. Details of its algorithm can be found in [59].

Table 2: Example of search tasks along with sample queries written by children in each search session. * indicates that the child initiated the search using the exact keywords in the search tasks assigned to them. Note that in the example queries, we left misspelled queries as they were actually written.

Session	Search Tasks	Queries
QS1	Name 3 countries and their capitals other than the USA	countries
	How tall are elephants?	how tall are elephants *
	What is inside a cocoon?	cocoo
QS2	Situational and not specific prompts, e.g.	amelia badelia the boo
	You are at your friend's house, how will you search for interesting books	janotors book
	to show them on their computer?	harry potter

on 593. For analysis purposes, we grouped the queries written by children into four types:

- ***Misspelled Queries:*** Queries that contain one or more terms that are not correctly spelled, e.g., "*tomas and freinds*".
- ***Informational Queries:*** Queries that are meant to lead to resources that can enlighten a user about a topic of interest, e.g., "*dolphin mammal*" and "*giraffe neck bone length*".
- ***Question Queries:*** Queries written in the form of a question. They usually begin with tokens such as "how", "when", or "what"; for example "*how tall are elephants*".
- ***Incomplete Queries:*** Some queries where the last query term was not completely spelled, e.g., "*Arizona Capi*" (which should be "*Arizona Capital*") and "*Amelia badelia the boo*" (which is meant to be "*Amelia badelia the book*"). Hence, we categorize these type of queries as incomplete.

We summarize the per-type distribution of queries collected in QS1a, QS1b, and QS2 and the results from query analysis in Tables 3 and 4, respectively. We further offer insights, discussion of our findings, and illustrative examples pertaining to query types below.

Table 3: Frequency of queries grouped by type in different sessions.

Query Type	QS1a	QS1b	QS2
Misspelled	37%	64%	34%
Informational	22%	40%	32%
Question	31%	35%	19%
Incomplete	7%	17%	16%

4.2.1 Misspelled Queries. Previous studies show that children misspell queries more often than adults, as a result of their limited vocabulary [42]. Children tend to emphasize their query, e.g., "*aammaazzinng burger*" or even write queries with spelling errors, e.g., "*ffrnen*", making it difficult for any query suggestion algorithm to interpret possible query intent to offer suggestions.

We observed that in QS1b and QS2, Bing and ReQuIK had comparable performance in terms of interpreting queries with misspellings. This meant that there was not a strategy that was most often favored when providing suggestions in response to misspelled queries (see Table 4). We noticed that for queries that included severe misspellings, such as "*ffrnen*" ReQuIK was not able to offer any suggestions, whereas its counterpart was able to at least propose some alternatives, e.g., "*french ireland*" and "*french*". Consequently, we are not surprised to see that in QS2 Bing's suggestion were more often favored. It is worth mentioning that when it comes to misspelling interpretations, Bing also seemed to offer more topical diversity among its suggestions, which in some cases lead to suggestions that better captured the intent of a child-initiated search. For example, for the search task ***what is inside of a cocoon***, we found that in response to the query "*cocoo*", ReQuIK offered suggestions such as "*coco movie times*" and "*coco the movie*" (referring to a character in a children's movie). Bing was able to identify that the purpose of the search could also refer to *cocoons*, and therefore suggested "*cocoon*" and "*cocoon movie*". Being able to interpret a misspelled query and offer suitable suggestions is imperative, as this should lead to resources that satisfy children's information needs.

Table 4: Summary of children's preferred suggestions grouped by query type and suggestion algorithm.

	QS1a		QS1b		QS2	
Query Type	Bing	ReQuIK	Bing	ReQuIK	Bing	ReQuIK
Misspelled	41%	59%	40%	60%	56%	44%
Informational	61%	39%	41%	59%	49%	51%
Question	25%	75%	35%	65%	42%	58%
Incomplete	48%	52%	43%	57%	44%	56%
Average	**43.7%**	**56.3%**	**39.8%**	**60.2%**	**47.8%**	**52.2%**

4.2.2 Informational Queries. Compared to adults, children are known to write queries that have a more *informational intention* [40]. Research shows that they prefer web resources that have an explanatory information [43]. We manually classified informational queries using the guidelines introduced by Jansen et al. [47] (this study uses the Broder [25] query categorization).

For informational queries in QS1b and QS2, children preferred suggestions from ReQuIK (59% and 51% respectively, in Table 4). For example, when assigned the task of ***finding interesting information about dolphins***, for the query "*dolphin mammal*" ReQuIK suggested "*what makes dolphin a mammal*" and "*is a dolphin a mammal or porpoise*", whereas Bing suggested "*dolphin mammal*" and "*dolphin mammals*". For this search, children favored suggestions from ReQuIK, which we attribute to the fact that ReQuIK's suggestions were topically diverse when compared to Bing's which only modified the original query to its singular and plural form.

In QS1a, children preferred the suggestions offered by Bing. We infer that Bing had an advantage over ReQuIK due to its ability to interpret long, natural language queries that did not include spaces. Recall that in QS1a, suggestions were triggered by the space button. We observed that children quickly realized this and proceeded in formulating their queries without including spaces. For instance, they wrote "*whatisaherpathologist*" instead of "*what is a herpathologist*". For these queries, Bing was able to parse and offer possible suggestions; for most cases ReQuIK was not equipped to do so.

4.2.3 Question Queries. Similar to Torres et al. [34], we manually classified question queries based on the presence of tokens such as "how", "what", "when", "why", and "who". Some examples of question queries we found among those written by children were "*what is minecraft*" and "*how do you make ice*".

For question queries, children preferred ReQuIK over Bing in all sessions (75%, 65%, and 58% in QS1a, QS1b, and QS2 respectively, as shown in Table 4). We infer that this was the case because ReQuIK offered suggestions that included terms that children are more familiar with. Furthermore, we noticed that in QS1a and QS1b, children used as queries the keywords present in their assigned search tasks. This was particularly prominent for question-like search tasks. For example, for one of the task children were prompted to find out ***how tall are elephants***. We saw that most children used the exact keywords in the prompt to initiate the search. In response to that, ReQuIK provided suggestions such as "*how tall are full grown elephants*" and "*how tall are newborn elephants*", while Bing's suggestions were "*how tall are elephants*" (i.e., the original query), and "*how tall are elephants in feet*".

4.2.4 Incomplete Queries. One goal of offering QS is to interpret queries that may not be written completely by users and provide the most likely suggestions that addresses their information need [21]. Recall that we treat a query as an incomplete one if its last term is not fully spelled.

As shown in Table 4, children preferred the suggestions offered by ReQuIK for their incomplete queries in all sessions. As an example, consider "*amelia badelia the boo*", one of the queries created for the QS2 task focused on locating ***information about books that interest them***. Bing suggested "*amelia badelia the movie*", which does not capture the intent of the search topic, i.e., books as opposed to movies. Alternatively, ReQuIK suggested "*amelia bedelia books reading level*" and "*amelia bedelia book read online*", which were often selected as suitable suggestions.

4.3 Query Term Analysis

In addition to the different query types, we examined children's preference for suggestions offered in response to (i) queries with terms that refer to children's pop-culture and (ii) queries with educational terms.

- ***Children Popular Culture Terms:*** These are queries that contain terms that relate to entertainment for children, such as children movies, music, story books or games. Examples of queries in this term category include: movies–"*frozen disney*", music–"*baby bumble bee*", books–"*amelia badelia*", and games–"*minecraft modes*".
- ***Educational Query Terms:*** These are queries that include terms that relate to subjects that children are taught at school, such as Mathematics, Science, or Government. Examples of queries in this term category are: Mathematics–"*area of a triangle*", Science–"*giraffe neck length*", and Government–"*capital of Arizona*".

We present a summary of the per-term distribution of queries we collected in QS1a, QS1b, and QS2 in addition to an overview of the findings results from query analysis in Tables 5 and 6, respectively. In the remainder of this section, we present our analysis of the query terms and use examples to illustrate our results.

Table 5: Frequency of queries grouped by terms in different sessions.

Query Term	QS1a	QS1b	QS2
Pop-culture	22%	22%	19%
Educational	17%	20%	42%
Others	61%	58%	39%

4.3.1 Children Pop-Culture Terms. We manually classified queries containing popular culture terms, i.e., that relate to entertainment for children such as movies, books, music, and games. Some examples of queries we found among the ones written by children were "*coco*", "*ferdinand*", "*harry potter*", "*amedia badelia book*", and "*minecraft*". Our analysis of these queries revealed that there was not a strategy that children particularly favored in the presence of queries that included pop-culture term.

Preferences for QS1a, QS1b, and QS2 for both Bing and ReQuIK are around 50% (Table 6). For instance, in response to the query "*harry potter*", ReQuIK suggested "*harry potter and the cursed child movie*", while Bing's suggestions included "*harry potter quizzes*", "*harry potter world*", all of them equally appealing to children. We did see some particularly interesting queries for which the suggestion-generation strategy explicitely targeting children fared better: for the query "*coco*", ReQuIK provided suggestions such as "*coco movie review*" and "*coco full movie english*". However, some of the suggestions that Bing offered were "*coconut oil benefits*", "*coconut oil*", with only one suggestion, i.e., "*coco movie*", including terms more appealing to children.

Table 6: Summary of children's preferred suggestions grouped by the query term and suggestion algorithm.

	QS1a		QS1b		QS2	
Query Term	Bing	ReQuIK	Bing	ReQuIK	Bing	ReQuIK
Pop-culture Terms	48%	52%	49%	51%	54%	46%
Educational Terms	100%	0%	33%	66%	49%	51%
Average	**74%**	**26%**	**41%**	**59%**	**51.5%**	**48.5%**

4.3.2 Educational Query Terms. Nowadays, children use search engines for their educational searches, which usually takes longer when using printed books [55]. They can conveniently and efficiently look up the meaning of words like "w*hat is a herpetologist*" or science related questions such as "*how tall is a giraffe*". For our analysis, we treat a query as educational if it includes terms related to children's class subjects. We were interested in knowing how children responded to the suggestions provided from a general-purpose and child-oriented suggestion algorithm, for their education-related searches.

As shown in Table 6, in QS1a, no child selected the suggestions offered by ReQuIK. As previously mentioned, we infer that this was attributed to ReQuIK's inability to provide suggestions for longer queries that did not contain spaces (we found that the educational queries were longer compared to the other queries written by children). For QS1b and QS2 children preferred suggestions offered by ReQuIK for their educational searches (66% and 51%, respectively). For example, in response to the query "*giraffe neck length*", some of the suggestions offered by ReQuIK included "*giraffe neck bone length*" and "*giraffe neck vertebrae length*". Bing, however, suggested "*giraffe neck length*" which only corrected the misspelled term in the query, and "*giraffe neck evolution*". We attribute this outcome to ReQuIK's ability to generate suggestions that are topically-relevant for young audiences that include, whenever possible, child-friendly terminology.

Overall, children preferred topically diverse, child-friendly suggestions, but did not like those that included terms such as "for kids" or "for children". While children favored suggestions oriented to them, we argue they prefer not to be labeled.

5 PARTICIPATORY DESIGN LESSONS FOR QUERY SUGGESTIONS

The tool survey and pilot study establish that there is a need for child-directed QS. In this section we pursue a Participatory Design (PD) approach using the Cooperative Inquiry Method [37, 45, 75] to inform future research in this area. Cooperative Inquiry allows children and adult researchers to work closely together as design partners.

5.1 Design Method

We use Cooperative Inquiry with our intergenerational design team consisting of adults (investigators, undergraduate and graduate students) and eight children (4 girls, 4 boys) ages 7-11. The number of adults varied each day, one of them (a co-author) has participated on design teams like this for 15 years and has worked with mentoring new adult design partners. New adult participants are briefed on their role as design partner and facilitator. We employ many techniques to equalize power dynamics between the adults and children [37]. In terms of the children, half had participated on the team the previous year (September-April), and half had started on the team a month prior to the first session described below. The team meets regularly (twice a week), and works on various projects (not just this project) and were thus already familiar with one another before the design sessions described below were conducted.

Each design session is 90 minutes long. The first 15 minutes are an informal snack time to help the team transition to the environment and prepare for collaborative intergenerational work. After snack, there is a circle time where we introduce each other (if new people are attending) and ask the Question of the Day to help team members get to know one another better. Finally, we discuss the day's planned activities to set a purpose for the session. Following circle time we do the design work which generally takes 45 minutes followed by a 15 minute discussion or sharing time. For each session, we select a design technique that best matches the topic and goals of the session. After the children leave, there is a debrief session where the researchers look at artifacts, discuss outcomes, and gather notes which are then combined into a summary of the day's outcomes.

Leveraging this model, we explored children's search interfaces using two techniques: Big Paper and Mixing Ideas [37, 44] over five design sessions (described below). It is of note, that while the starting point of these sessions was more general than that of QS (i.e., the broader scope was that of designing a new online search tool for children) many of the big ideas that came out of the sessions related to QS and as such are highlighted here.

5.1.1 Design Session 1: Big Paper (Oct 2018). We asked children to design a new search tool that would allow them to find the things they look for online. In introducing the topic of online search, we referenced popular online search tools that the children are familiar with – Google and Bing – and asked them to design a new tool specifically for children. We used the Big Paper technique in this session, where small groups worked collaboratively on a large piece of paper to design a search tool. Three groups of four (children and adults) worked throughout the session. Space was adequate so that each group was able to work on their own without being influenced by other groups' ideas.

5.1.2 Design Sessions 2-4: Mixing Ideas (Oct-Nov 2018). Mixing ideas is a structured way of having a group of children progressively mix their ideas together to result in a collaborative "final" low-tech prototype [44]. It starts with individuals designing a prototype, then pairs *mix* their ideas, and groups merge and grow until there are only one or two final prototypes from which to glean big ideas to incorporate into the next iteration of the design (e.g. a working prototype). Although this technique was primarily developed to facilitate collaboration among younger children (ages 4-6), our group has found it helpful to use with older children (ages 6-11), particularly when the team is new or there are new members on the team. It is also helpful as a large amount of insights are gathered from the smaller groups, and suggestions progressively hone in on the major points that need to be incorporated into a design. Over three sessions, we allowed individual team members to create a design (Design Session 2), then had pairs mix their ideas (Design Session 3), and then merged the pairs into a total of two groups (Design Session 4).

5.1.3 Design Session 5: Big Paper (Dec 2018). We asked children to design and improve QS. To prime the discussion, we described how popular search engines do this by providing text options underneath the query box. We also gave them some initial query words (e.g. snake, Boise, frozen, cookie) along with the query suggestions that Google provided for each of the words. Each of these were printed on small pieces of paper the children could glue or tape to the big paper illustrating their query suggestion mechanism. Alternatively, they could not include the suggestions and provide their own original suggestions. This approach was intended to give us insight not only about their preferred way of interacting with QS but also provide some additional insights into the kinds of suggestions they thought would be useful. For this activity there were four groups of 3-4 (children and adults). Space was adequate so that each group was able to work on their own without being influenced by other groups' ideas.

5.2 Design Session Observations and Outcomes

We share observations and outcomes from each design session.

5.2.1 Design Session 1: Big Paper (Oct 2018). The design of the new search tool had several similarities among the three groups. These included social aspects and interactive aspects. The most common social aspect included up- and down-voting of results in a collaborative fashion so one could indicate what they liked and see what others thought were effective responses. One group proposed incorporating a chat feature so users could search for things online with friends and peers. Similarly, another group favored including a "contact a friend" feature. There were two groups that recognized the need to differentiate users so you knew who was who and to store information about users and past searches, but recommended a simplified "logging in" mechanism that consisted only of a username (no password).

One of the aspects that was uniform across all groups was a simplification of the interface so as to not include scrolling, but rather looking at a single result at a time and explicitly (via an up or down vote) or implicitly (by going to the next item) indicating whether or not it was appropriate. Two groups described interfaces that animated to the right on going to the next result, yielding something similar to horizontal scrolling. While horizontal scrolling is uncommon and generally seen as negative, recent literature supports this as a way of navigating results particularly on mobile devices [53] which are regularly used by younger populations. One group proposed categories or groupings of results (similar to QS), that would enable users to zoom in through a tunnel to more refined results, but would show a result at that level.

5.2.2 Design Sessions 2-4: Mixing Ideas (Oct-Nov 2018). In order to *mix* ideas progressively from smaller groups, we conducted three sessions that resulted in two *final* prototypes. One of the most common aspects of these sessions was the utilization of the term *categories* to describe helpful items related to the query that had been entered so far; i.e., children used categories to describe QS.

In the second design session (the first session of mixing ideas) each child designed their own search tool. Some of the similarities among the designs related to visuals and multimodal aspects to see and hear elements related to a search; including reading words or hearing sounds related to categories and results. Three of the eight child prototypes included mechanisms via categories to implement a form of "Did you mean something else?" (see Figure 4 as an example). Some utilized categories as a query refinement mechanism to display several categories. Many of the children expressed that once they had finalized their query, they generally expected their searches to understand exactly what they wanted.

In the third design session (the second of mixing ideas) the children worked in pairs along with one or two adults. The prominent themes from this round included a continuation of the prevalence of categories, visuals, and multimodal aspects (i.e., images and audio), search refinement, and a simplified rating system (only up-voting). All groups mentioned some mode of categorization. Slightly different from the previous session, instead of "Did you mean something else?" the children called for more categories to be provided automatically.

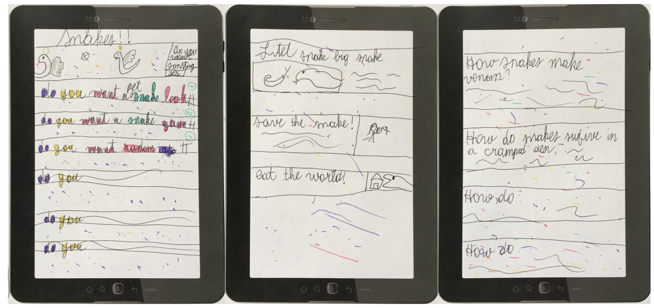

Figure 4: Examples of QS a children's search tool would provide (as indicated by a 10 year-old girl).

In the fourth design session (the third and last of the mixing ideas) there were four children in each group along with 2-3 adults. The commonalities between the groups in this session were: categories, spelling suggestions, and visuals that helped confirm understanding. One group proposed a mind-map-like query suggestion mechanism (though the children did not term it that way). This is interesting and while it has been proposed in the past [19, 58], it has not resulted in usage in search tools. Of note, the rating and voting systems mentioned in previous iterations of mixing ideas were not as prevalent in the final designs. One of the groups did include a *like* button on their query results, but otherwise this was not nearly as prominent as it was in earlier rounds.

5.2.3 Design Session 5: Big Paper (Dec 2018). This design session was focused on QS. Since the term *query suggestion* was described to the children, they started using this terminology more – whereas previously they seemed to refer to the similar concept as *categories*. One particularly salient theme from this session was that all groups recommended that QS should be different than the ones provided by typical search engines and should include more information, such as links to free tickets, related event information, or information related in different ways than those provided. Three of the four groups indicated a preference that the location, current time, season, and weather should influence the kinds of results and query suggestions that are offered. For example, as this session took place in early December, the children felt the query "cookies" should automatically bring back results related to "Christmas cookies". Children also indicated that selecting a QS should lead to new suggestions and results, but navigating back would return to the previous state, visually "explode" (or fade) the visited query suggestion, and shows a new QSin its place.

All groups made suggestions within the category of visualization and personalization. They indicated that all QS should include a visual representation next to it to promote understanding, recognition, as well as to identify that there was mutual understanding between them and the system. Children also made several suggestions for visual representations and animations, such as exploding stars from the results if the query was about stars or reindeer pictures "flowing" out of the query box to indicate that the query was recognized. While, on the surface, these may seem to be just "flashy", they acted as a visual indicator that the semantic meaning of their query was understood (or not) by the system. By looking at the representation, users could quickly and readily perceive if their query intent was understood.

Another visual cue mentioned was the physical layout of the query suggestions. One design had the suggestions laid out in the shape of the first letter of their name. The other three had some similarities in that their were different locations and/or colors representing spelling corrections and QS. One had these in very different parts of the interface, which would obviously be difficult to navigate, but others mentioned perhaps having the spelling correction above the query box, and the related categories or query suggestions below. An important lesson learned was that the children recognized and distinguished that QS are different than spelling help.

Some of the team's designs borrowed from what exists in current popular query suggestion mechanisms, like not duplicating repetitive words (similar to how Google does their QS), and having an ellipsis before to indicate that it was copied or repeated. However, other solutions emerged that were different from current solutions like re-ordering query words in the suggestions "Boise trees" shows "Buying Christmas trees in Boise" as a possible suggestion.

There were designs that limited the number of QS that could be displayed, but allowed for more to be shown. One design simply had a *more* button at the bottom of the QS list (to show more suggestions), as well as an 'X' button on suggestions to remove them from the list. When an item was removed the computer would "remember" and a new suggestion would appear. Another design idea was to show a limited number of QS and on mouse over they would show small "pop-ups" with more sub-suggestions in a hierarchical manner.

An additional item noted was that speech emerged as an option to enter the query, but groups seemed to think that audio was not sufficient to represent the results. As indicated previously, audio output was suggested as a potential avenue for confirming the user's search intent.

5.3 Query Suggestion Design Lessons Learned

In summary some of the query suggestion preferences indicated by children, include:

- Visuals can readily help users recognize whether or not their search intent was understood by the computer and that an accurate response was returned.
- QS (and search results) should not just take into account users' history, or age appropriateness, but also temporal information, e.g., location, current time, and season.
- Spelling corrections differ from QS. They ought to be in different places and/or have different colors.
- Children realized that QS are different than spelling help.
- Audio output emerged as a modality to confirm that the QS matches the user's search intent.

6 CONCLUSION AND FUTURE WORK

For decades, researchers have presented strategies aimed at easing search tasks for users. Yet, when it comes to young audiences, there are many open questions that require attention.

In this paper, we dedicated our research efforts to further studying the query formulation problem from a child's perspective. We first analyzed how existing web technologies, i.e., search engines, browsing websites and plug-ins, used by children assist them in formulating queries. Our examination indicates that children receive little assistance when formulating queries to initiate the search process and that the help provided tend to be limited to either misspellings or boolean formulation or question-queries. This demonstrates the need for more research in this area and for designers of search tools to include a functionality that can facilitate the construction of queries.

To better understand children's interactions with query assistance technologies, we focused on QS as a common strategy. We examined query and QS interaction logs from a pilot study with young children in order to better understand their preferences for suggestions generated using two algorithms: ReQuIK's, targeted to children, and Bing's, designed to serve a general audience. Results showed that most of the time, children favored suggestions tailored towards them, as opposed to those often presented to search engine users. Children specially preferred ReQuIK's suggestions for queries that they wrote in the form of questions or that were incomplete. ReQuIK however failed to offer suggestions for long natural language queries, which is a limitation as children may formulate their query in this manner.

Our observations from participatory design sessions with children confirm previous findings on how children formulate queries: most of the queries had spelling errors and had an informational intent [40, 41]. Moreover, we noticed that children frequently write queries in the form of homophones, i.e., as they sounded, when they did not know how to spell the queries. We also learned from our interactions with children that participated in our study that presentation matter, as font size of the suggestions, the color of the interface, and the number of suggestions showcases–less is more– are only a few of the important aspects that should be considered in the design of query-formulation technologies for children.

From our assessments, it is clear that when assisting children during query formulation, it is key to consider multiple perspectives. Given the discussion presented in this manuscript – the manner in which children currently express their information needs, writing patterns intrinsic to this particular audience, and diverse reading and comprehension abilities among young users – we argue that the design of new or improved query-formulation technologies that can enhance information discovery require interdisciplinary efforts with participants from human-computer interaction, information retrieval, natural language processing, education, and literacy research communities, to name a few. This will lead to holistic solutions that are better tailored to children. More importantly, this should also foster solutions that can leverage existing research on search as learning (in its majority for adult audiences) [28, 62] and thus facilitate learning to formulate queries for completing successful search tasks, while searching for information either for education or entertainment purposes.

In the future, we will perform further studies to examine how children interact with other available query formulation strategies. In doing so, we will investigate how these child-oriented strategies can lead them to resources that meet their information needs. Finally, we plan to go beyond strategies available for English speakers.

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8 SELECTION AND PARTICIPATION OF CHILDREN

The query suggestion pilot study consisted of 8 children (5 girls, 3 boys; ages 6-10). The design sessions were conducted with an intergenerational design team that meets twice a week after school that consisted of eight children (4 girls, 4 boys; ages 7-11). All children were recruited via publicly posted flyers and local social media outputs. The purpose of the investigations were explained to participants and their parents. Parents signed consent forms to allow their children to participate, and children assented to participating.

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