Getting to Know You: Search Logs and Expert Grading to Define Children's Search Roles in the Classroom

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Abstract

In this paper, we examine the roles children play when using web search engines in the classroom context by revisiting, not replicating, a seminal work set in the home context. In particular, we describe how we juxtaposed performance indicators inferred from a combination of search logs (collected over two years) and expert grading of completed inquiry assignments to discern emerging search roles among children in primary four and five (aged 9 to 11). In light of the COVID-19 pandemic, we also explore differences when a traditional classroom is replaced by online instruction at home. Lastly, we discuss future research directions that we see as pivotal to advance research in Information Retrieval to and for children.

Keywords

Children, Search Engines, Search Roles, Information Retrieval

1. Introduction

Mainstream search engines are designed to serve "large commercial masses", i.e., adult searchers. Still, children are known to favour popular search engines [1, 2] even if that causes them to face well-studied barriers, for instance formulating succinct keyword queries or swiftly navigating search engine result pages (**SERP**) to identify relevant resources [3, 1, 4, 5].

The obvious need for search engines to more effectively serve children, has motivated researchers to study children's search behaviour from a *system* perspective in addition to design algorithmic and interface functionality tailored to children [6, 7, 8, 9]. Research from a *user* perspective, however, is more limited. Seminal work in this area is the one by Druin et al. [10], who define *seven roles* that children play when searching at home: **non-motivated** searchers stop at the first result and use SERP snippets instead of exploring retrieved resources; **distracted** searchers are easily attracted by other activities around them and quickly abandon the search task without completing it [11]; **visual** searchers look for non-textual materials to quench their thirst for information; **rule-bound** searchers follow strict steps to compensate for a lack of confidence in searching; **developing** searchers make an effort to learn how to search but are not yet able to deal with complex searches; **content** searchers go back to familiar websites; and **power** searchers are confident and competent in using search tools across leisure and education-related searches.

As stated in [10], these roles showcase the range of skills and aptitudes that children exhibit when searching at home [12, 3]. Searching, however, is not limited to this context as it is commonplace to embed search engines in the classroom–they are convenient and valuable assets for children's education [6, 13]. At home "children have a freer access to the computer and encounter a wider and more incidental array of search topics, as opposed to the constrained topics [...] in the school" [3]. In the classroom, however, information seeking involves locating online information in order to learn [14, 15]. This is not a trivial task, especially if we consider children's widespread developing abilities to search, or lack thereof, due to limited search literacy instruction [13]. Further, in the classroom context, there are factors that define the search experience that differs from those at home. Distinguishing factors include (i) the fact that the search task is set by teachers, (ii) there is an extrinsic motivation provided by the grade assigned to outcomes of the search task, (iii) there are fixed deadlines for search task completion, and (iv) teachers and peers can offer varying levels of direct and proactive support.

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The departure from the home context leads us to question whether the skills and aptitudes for search remain the same in the classroom. We seek to better understand search roles children play in the classroom context and recognise any new roles that spontaneously manifest as a result of scrutinising context-dependent data. Unlike Druin et al. [10], who use interviews and observations while engaging children in simple, as well as multi-step search tasks and hence take a qualitative approach to discern roles, we take a *quantitative* approach. We rely on performance indicators inferred from search logs and teachers' observations collected via user studies involving 172 children who conducted web searches in the classroom context. Data collection took place over a two-year period at two Italian-speaking European schools, enabling us to gather evidence of children's *natural interactions* with search tools. Midway through this data-gathering period, the COVID-19 pandemic caused classrooms worldwide to move to the home context. This afforded us a unique opportunity to explore children's search roles in traditional vs. online classrooms.

Our exploration describes a prospective approach for identifying search roles based on quantitative indicators, it also offers insights on other roles potentially played by children in the classroom context and ways in which technology could better support information seeking. Lessons learned can inform the design of web search technology for the classroom that can offer the scaffolding young searchers need to successfully complete search tasks for learning regardless of their in-development (search) skills.

2. Data Collection

We base our exploration–aimed at understanding how children search for information in a classroom context–on data collected via several related user studies we conducted between September 2018-2020 [16, 17, 9]. Given the longitudinal nature of the collected data (summarised in Table 1), to enable analysis across studies we followed the framework proposed in [17], which establishes four pillars to study and evaluate information retrieval systems for children: *user group*, *task*, *context*, and *search strategy*. In our case, children in primary four/five, looking for information to answer questions related to the school curriculum, in a classroom context, using the same search tool altered with diverse interfaces.

2.1. Participants

Study participants included 172 children (ages 9 to 11) in primary four and five classrooms in two Italian-speaking schools in two European countries (Italy and Switzerland). Children had varied exposure to digital tools and broad expertise using search tools to support learning; making them a representative population for primary four and five classrooms.

Table 1
Details of the studies conducted for data collection purposes, resulting in the search logs and teachers' observations leveraged in the exploration presented in Section 3.

	Study 1	Study 2	Study 3
Source	[17]	[16]	[9]
Participants	75	66	31
Age group	9 - 11	9 to 11	10-11
Topic	Tornadoes, volcanoes, pyramids, endangered animals	Environment	Ancient Rome
Interface	Traditional vs. voice	Traditional	Traditional vs. emoji-enriched
Context	Traditional classroom	Traditional classroom	Online classroom

2.2. Protocol

In each study, teachers presented their class with an inquiry assignment related to a topic aligned with regular curriculum instruction. Children had to respond to questions (4 to 12, depending on the study) on subjects including science, geography, and history. These questions ranged from a description of political life in ancient Rome to ways to prevent ecological disasters and how to recognise different types of volcanoes. Further, some questions were fact-based (e.g., "What is the island of plastic?") and others open-ended (e.g., "How were the pyramids built?") to capture user interactions when addressing inquiries of increased complexity.

To locate information to answer said questions, children used a search tool resembling a popular search engine (powered by Bing's API; language set to Italian). The interface of the search tool varied across studies, allowing us to more closely look into the wide-ranging roles that materialise while children search. In `Study 1`, in addition to a traditional text-based interface, children used a vocal search assistant, an interaction medium now en-vogue. In `Study 2`, children interacted with a traditional interface. In `Study 3`, children engaged with a traditional interface, as well as emoji-enriched interfaces, where emojis served as relevance clues for SERP results.

2.3. Data

We examine search logs generated on each study, as they capture user interactions with search tools. If available, we consider direct observations and teachers' assessments (i.e., grade) of submitted inquiry assignments. These provide additional insights on the performance of each student, as well as the mood and attitude of the

children while engaging with the proposed search tasks. Whenever possible, teachers monitored the nature and timing of children's requests for guidance and support. All essential elements for better understanding how children relate to search tools in the classroom.

2.4. Exploration

We scrutinise well-known performance indicators: session length, number of queries, number of query terms, number of clicks, rank position of clicked resources, number of positive/negative clicks (clicks on known relevant/non-relevant results as defined by teachers), click accuracy (proportion of positive clicks over total clicks), and assignments' grade–a score between 0 and 100 experts (teachers) assigned to the responses children submitted after using search tools to locate relevant information related to the corresponding inquiry assignment.

We look into indicators' distributions and, when befitting, cluster searchers portraying similar behaviour into three groups we denote: upper, medium, and lower. For instance, consider the click accuracy depicted in Figure 1. In this case, searchers in the lower quartile belong to the *lower* group; those in the upper quartile are in the *upper* group; remaining searchers are in the *medium* group.

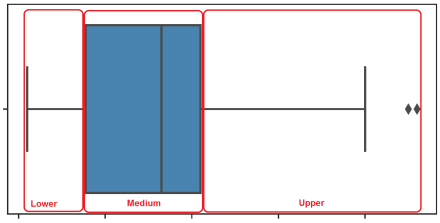


Figure 1: Segmentation of click accuracy distribution to group searchers.

3. Analysis and Discussion

In this section, we discuss how we map, whenever possible, quantitative indicators with each of the roles originally defined in [10]. Note that search roles in [10] are *not mutually exclusive*, i.e., they do not set a partition on young searchers and the role they play while searching as a child can play more than one role in their many interactions with search engines. Further, some roles are more closely related to others. For example, the developing searcher role is often combined with the rule-bound, content, and distracted searcher roles. By changing the context (from home to classroom), and the data source (explicit in the original study to primarily implicit here), we anticipate variations on the emerging roles.

Table 2
Study performance indicators. * indicates statistically significant difference with `Study 3` (t-test, $p < 0.001$).

Indicators	`Study 1`	`Study 2`	`Study 3`
# of Clicks/session	4.70 (3.73)*	5.91 (5.93)*	2.91 (2.60)
# Queries/session	4.51 (6.68)*	6.88 (11.90)*	2.15 (1.47)
Avg. query terms	5.77 (3.29)*	5.68 (3.02)*	6.98 (2.98)
Avg. click position	5.77 (3.29)	–	5.68 (3.02)
Session length (s)	1357 (1062)*	–	106 (184)

3.1. Can we capture search roles using quantitative indicators?

We discuss whether, how, and to what extent the seven search roles presented in [10] for the home context are mimicked in the classroom context. In Table 2, we summarise performance indicators across the studies. In Table 3, we report performance variations across searchers in different groups (low, medium, and upper) using the most distinguishing indicators as lenses for investigation. To illustrate search roles, we plot in Figure 2 the distribution of performance indicators inferred from the study with the least number of participants (i.e., `Study 3`).

The **power searcher** role is directly linked to school-related searches in [10], making it an ideal candidate to start our investigation. This role is the most straightforward to recognise and describe via implicit indicators. Children playing this role can search most autonomously, with minimal support from teachers and/or custom-designed search tools; children can perform all the necessary steps leading to a successful search: from translating their information need into a query to identifying useful (relevant) results. We look at the distribution of the number and position of clicks, as well as the number of clicks on known relevant SERP resources; we consider any above-average combination of these indicators as a clue for this role. We assume that power searchers would extensively click on relevant resources and be focused on task completion, thus we situate power searchers in the upper group emerging when considering click accuracy distribution (Figure 1). Samples power searchers are users 22 and 23 in Figure 2. In their case, the number of positive clicks is very close to the number of clicks (high click accuracy), yet they deviate from the expectation that children favour resources higher in the ranking by clicking on resources on lower-ranked positions, displaying their savviness and confidence with conducting online information-seeking tasks.

We associate the **developing searcher** role with children in the medium group for click accuracy (users 13 and 15 in Figure 2). From analysis of direct observations and grades, we note that click accuracy varies depending on the complexity of the task evidencing that children lack sophisticated search strategies, especially for recognising

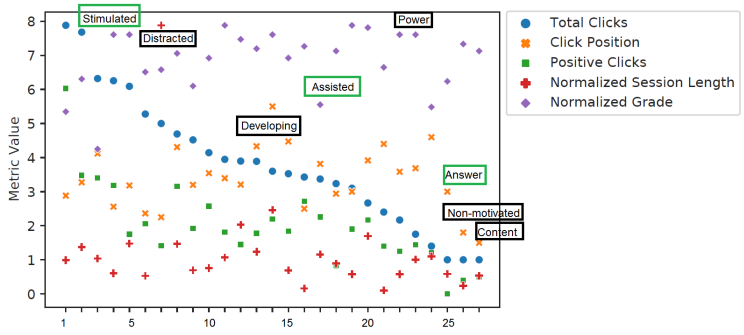


Figure 2: Performance indicators inferred from data collected during `Study 3`.

Table 3
Variations on performance indicators across user groups in `Study 3`.

Group by	Group	Session Length	Click Accuracy	# Positive Clicks	# Negative Clicks	Grade	# Query Terms
Click Count	upper	161.87	0.50	3.77	1.47	87	7.12
	medium	104.62	0.58	1.39	0.41	83.75	6.88
	lower	–	–	–	–	–	–
Session Length	upper	366.50	0.48	2.30	1.03	82.61	7.13
	medium	69.74	0.56	2.79	1.03	82.97	6.54
	lower	17.08	0.57	1.93	0.42	78.61	7.95
Click Position	upper	183.16	0.49	3.24	1.46	80.19	7.22
	medium	120.11	0.58	1.66	0.52	83.45	7.13
	lower	56.21	0.57	0.57	0.06	84.66	6.12
Grade	upper	118.45	0.61	1.90	0.80	95.69	6.25
	medium	139.40	0.51	2.24	0.99	86.44	6.65
	lower	113.02	0.59	3.45	0.66	62.52	8.28

relevant results.

We interpret unnecessary long search sessions as a sign of a **distracted searcher** role, particularly among children in the medium group for click accuracy who pose few clicks and obtain lower-than-average grades, which we attribute to them forgoing task completion (e.g., user 7 in Figure 2). We equate a very limited number of clicks (practically none) coupled with no depth in SERP exploration with the **non-motivated searcher** role. User behaviour portrayed by non-motivated searchers partially overlaps with that of children assuming the **content searcher** role. Here, children only look for the answer to the assigned search task but are not interested in any further exploration, thus they do not take full advantage of the natural opportunity for learning by searching. It is possible, however, to distinguish between content and non-motivated searchers by considering teachers' assessment of task completion: content searchers try hard and most likely succeed in finding answers to their inquiries (high grades in Table 3), whereas non-motivated searchers tend to minimise clicks and instead rely on SERP snippets to come up with the information needed to complete the assignment. Consider users 26 and 27 on Figure 2. The former with a short session, few clicks, and even fewer clicks on positive results exemplifies the non-motivated searcher role. The latter, with a higher ratio of clicks on relevant results, serves as an example of a content searcher.

It became apparent that it would not be possible to identify **visual searcher** and **rule-bound searcher** roles in the classroom context from performance indicators. To quantitatively define visual searchers we would need to analyse more closely the nature of the clicked results and define a heuristic to discern visual from textual content. A predefined list of resources known to provide support to children when running school-related searches (such as the educational digital content provided by Wizenoze [18]) or turning to existing approaches to automatically detect sites satisfying classroom requirements [19, 20], would be useful to recognise rule-bound searchers.

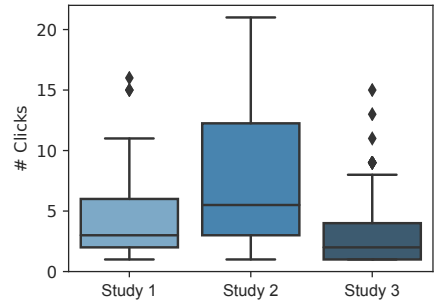
We noticed emerging trends that, while not aligning with any of the original roles in [10], offered insights into what we believe to be roles specific to the classroom context. Among the most prominent ones, we find

the **stimulated searcher** role, which accounts for the importance of emotional factors motivating the search. Figure 3a captures that children in `Study 2` clicked on more results than those in remaining studies. All studies followed the same protocol differing only on the topic of the search task. For `Study 1` and `Study 3`, we used impartial curriculum topics, e.g., tornadoes. The topic for `Study 2` was the environment–specifically, we asked children to find information about ecological disasters. From direct teacher's observations, we learned that children responded with great enthusiasm to search tasks expressing emotions even fear and rage. Children tried their best to complete the assigned task as a means to help the planet get better by understanding the causes for these calamities and prevent them from happening again. (A sample stimulated searcher is user 5 in Figure 2, with high assignment grade, above-average session length, and many clicks). From performance indicators–particularly the number of clicks generated–we notice the importance to set motivational tasks as these positively affect the behaviour of young searchers and their overall will to complete the task successfully.

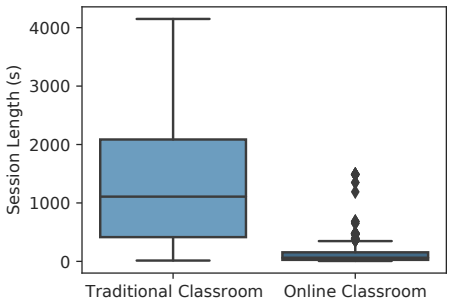
Another role we noticed merges the characteristics of the original power searcher and content searcher roles to yield the **answer searcher**. This role picks up on the search behaviour of a child interested in locating answers to the posed questions but not necessarily in the exploration of related information, which would be expected in the learning-by-searching experience. We recognise this behaviour by looking at the limited amount of clicks among top-ranked results when compared with that of power searchers who have the right combination of accuracy, depth, and width when clicking SERP results. We also see how answer searchers have an extrinsic motivation (the grade assigned by their teachers) as opposed to an intrinsic one (a genuine interest and curiosity for the topic of the search tasks). Indicators for user 25 in Figure 2 signal an answer searcher. Given that teachers can influence and motivate children when searching, we wonder whether the teaching mode has an impact on the roles taken by searchers.

3.2. Does teaching mode impact search roles?

Exploring whether search roles are impacted if classes take place remotely is not only a necessity during the COVID-19 pandemic [21] but it is also a common medium among families who chose to home-school children supported by online education [22] and online distance education (among rural populations) [23]. We again turn to quantitative indicators, but rather than considering the classroom context as a whole, we explore search logs generated on traditional classrooms (i.e., `Study 1` and 2) vs. those from online ones (i.e., `Study 3`).



(a) Click distribution. Significant difference between `Study 3` and the other distributions; `Study 1` and 2 are not significantly different (ANOVA with LSD post-hoc pairwise comparison $p \ll 0.001$).



(b) Session length in different classroom contexts.

Figure 3: Explorations across studies and contexts.

From Figure 3b, it is apparent that session length changes dramatically from the traditional to the online classroom context. This could be caused by several factors influencing children's transition to online classes. Together with the cognitive overload from conducting learning tasks completely online, children miss the aid provided by teachers/peers in the form of natural exchanges taking place when they are all physically together sharing the same space. These considerations align with those in [3], in light of the importance of the social dimension of searching among adolescents. A classroom is a social place with specific rules and dynamics. From teachers' feedback, we envisage children longed for exchanges with their peers as well as formal/informal guidance provided impromptu by teachers, if and when necessary. Indeed, the online classroom context prevented teachers from spotting critical situations when they could have otherwise intervened. For instance, teachers could not offer struggling children extra help in deconstructing complex search tasks or offering clarifications to make them better understand the search, i.e., what information needed to be found among SERP results.

Table 4
Overview of children's search roles in the home and classroom contexts.

Role	Home	Classroom		Main Indicators	Observations
		Traditional	Online		
Visual	✓			—	Based on available indicators could not be determined for the classroom context
Rule-Bound	✓			—	Based on available indicators could not be determined for the classroom context
Developing	✓			Click accuracy	
Content	✓			Total clicks	
Non-motivated	✓			Total clicks	
Distracted	✓	✓	✓	Session length, grade	
Power	✓			Click accuracy	
Stimulated		✓	✓	Session length, total clicks	Searchers inspired to search due to emotion associated with the topic of the search emerged as a new role inherent to the classroom context
Answer		✓	✓	Total clicks	Expands the content searcher role to account for searchers who only strive to locate an answer to a posed inquiry, as opposed to learning as a result of searching
Guided		✓		Query length	Searchers that depend on peer/teacher assistance to enhance their overall search experience

This lack of spontaneous scaffolding surely affected the weakest searchers. It emerges from comparisons among lower and upper user groups in Table 3 that although weaker searchers exhibit similar behaviour (in terms of clicks and session length) to that of most successful ones, they are not able to recognise they have found enough information to provide the right answer to the proposed search task (evidenced on lower grade scores).

We see an increase in the average number of query terms in the online classroom context (Table 2); we attribute this to the lack of peers and/or teacher guidance that could advise on effective query formulation. These discoveries prompt us to define a new role, the **assisted searcher** representing children who depend on guidance to boost their overall search experience and success. (Among users with similar total clicks, session length, and positive clicks, user 17–a student with adequate search skills as per teacher's observation in a traditional classroom–obtained the lowest grade, exemplifying in Figure 2 an assisted searcher.)

3.3. Getting to know young searchers

We aimed to recognise search roles children play while searching in the classroom by relying on well-studied search performance indicators, teachers' analysis of students' outcomes after conducting inquiry tasks in a classroom context, observations, and search behaviour trends emerging from scrutiny of indicators in-tandem.

From preliminary analysis of a reasonably limited sample, we were able to discern most of the original search roles [10] and even emerging new roles that we put forward, based on performance indicators, which we summarise in Table 4. Outcomes from our context-related exploration evidenced why identifying a strong connection between the presence of emotions in a task and the motivation it generates among young searches can have implications on the design of innovative search tools for the classroom. Context comparison also brought to light the social side of searching in the classroom and the role teachers and peers play in the search process. These takeaways highlight our main contribution: better understanding of young searchers' behaviour.

We discovered gaps in how to define visual and rule-bound searchers; we also identified other factors that should be considered for analysis purposes when exploring search roles. This lead to another contribution: better understanding of how to design future studies to go deeper in our exploration of different search behaviours and factors impacting them.

Overall, we surmise that the development of heuristics for reusing and interpreting user data, as we have done in this exploration, can prove a valid alternative to expensive, and often hard to conduct, user studies while saving time to researchers, and more importantly, users.

4. Conclusions, Limitations and Further Research

Search engines are widely used to support learning. As children learn in their own way, it is natural to think that young searchers would have different search behaviours based on their search skills, experience, and ability. In their 2010 seminal work, Druin et al. [10] examined qualitative data and search observations to determine the roles that children play when seeking information at home. Grounded on their findings, we hypothesised that

children's search roles could be inferred as a result of quantitative analysis. Consequently, in this paper, we instead focused on the classroom context and attempted to 'capture' these roles using quantitative indicators estimated from data collected across longitudinal user studies involving children ages 9-11.

By relying on search logs generated by children in the classroom context, in addition to teachers' observations, we could study children's engagement with search tasks in a natural environment. This resulted in an initial picture of children's search roles in the classroom, as well as inspiration for the design of future studies that enable the collection and analysis of a combination of implicit and explicit data using non-artificial tasks and settings. Encouraged by the outcomes of our analysis of search roles among *children aged 9-11*, we plan to extend our work to include children of broader age ranges, as existing research also suggests that different searchers need a different kind of support [24, 25]. Children naturally take on different roles as they grow, learn, and experience varied search contexts. The degree to which context influences their ability to search is still an open question, and one we are currently exploring with children in physical vs. remote classrooms. It would be of interest to examine how different types of tasks require and benefit from different roles played by the young searchers. This, in turn, will advance knowledge regarding the relationship between roles and tasks.

More research is also needed to understand how innovative search tools can substitute or at least alleviate the lack of "just-when-needed" personalised guidance provided by teachers and supportive interventions by peers. This aligns with our findings on if, when, and how children take advantage of visual cues for relevant resources in their quest for online resources that can help them satisfy their classroom-related information needs [26, 27], while evidencing other factors that contribute to a deeper understanding of young searchers' needs and their many facets according to the different roles they can play. Accordingly, scaffolding strategies should be designed for each role. In particular, our study can inform the development of conversational search agents that aim to aid children throughout their search experience. Relevant work [28] proposes a conversational system that can interact with users to clarify their information need. However, as argued in the literature, the level of trust and bias that a system can have on a user is very different between adults and children [29, 30]. Therefore, our study and the derived search roles shed light on which young users need more help while in a search session. Moreover, we hypothesise that a conversational agent's actions can go beyond clarification or requesting for feedback, as a system can guide children in a search session (just like their teacher) towards the right set of actions. This aligns with our previous works [9, 25] where we studied how different relevance cues help children perform better in a search session. We assume that search cues are a form of scaffolding, and can be translated into an agent's actions in a conversation (e.g., a relevance cue in a search session can be considered as an agent's action in which it mentions a certain document might be useful). Based on the searcher profile and the required cue, an agent can decide when and how to intervene.

The discussions presented in this paper can set the foundation on how to recognise and forecast the search roles children play while searching for learning specifically in the classroom setting (traditional or online). While preliminary, outcomes from our analyses evidence the need for a long-term commitment from the Information Retrieval community to advance theoretical and practical knowledge regarding the design of (multi-modal) search tools for children–tools that offer voice, text, and conversation as means to best address searchers' needs while minimising classroom distractions [24, 31]. Design is naturally coupled with evaluation, which when it comes to children and information retrieval systems is not an easy feat [32]. We attribute this to (i) the lack of dedicated datasets and events like TREC or CLEF that could ease development and comparison across proposed algorithmic solutions for which children are the main stakeholders, in addition to (ii) the need to explore assessment metrics that go beyond the traditional NDCG, precision, or mean reciprocal rank [33], in order to simultaneously account for the complex demands imposed by the goal of the search task (learning) [34] and needs and abilities of the target audience (children of broad age ranges) [35, 36].

A good starting point in this transition from theory to practice is the exploration reported in [27], where children participated in co-design activities to define their natural sense for relevance. Outcomes revealed that relevant results for children were those that would act as an open window enabling them to look outside and go and explore further, explain obscure concepts, and/or highlight material suitable for children in the classroom. Therefore, a relevant result should be stimulating, explicable, and understandable. Even if we often saw a consensus on what relevant means for children, we also noted that when engaging with search engines, not all children would recognise which results on a SERP were, in fact, relevant. This could also be due to teachers and children having a different sense of relevance [26], a mismatch to account for when tuning into children's perspectives as determined by their search roles.

We posit that leveraging findings from our appraisal of search roles we can advance knowledge towards algorithmically determining *who* needs support for relevance detection–whether that be in the form of visual clues augmenting traditional SERP or dedicated interfaces– and *when* that support is indeed needed.

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