

Scripting For Collaborative Search Computer-Supported Classroom Activities

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ABSTRACT

Searching online is one of the most powerful resources today's students have for accessing information. Searching in groups is a daily practice across multiple contexts; however, the tools we use for searching online do not enable collaborative practices and traditional search models consider a single user navigating online in solitary. This paper presents a three level conceptual model, called the Collaborative Search Procedural Model, which enables the implementation of collaborative search classroom activities based on multi-user collaborative search scripts. A software solution, CollSearch, which follows the Collaborative Search Procedural Model and offers a unified tool to enable collaborative searching computer-supported classroom activities, is also presented. Empirical evaluation of the tool with high school students as part of an English as a second language course shows that students' outcomes improve when compared to non-scripted group search. Results show that by following the Collaborative Search Procedural Model students better appropriate the work they build together with their group. The OECD has highlighted the importance of collaborative work by the fact that PISA 2015 will assess collaborative problem solving; collaborative search is a fertile field for fostering better group work interactions. This paper shows that new tools that enable collaborative work dynamics in searching for information must be developed in order to address the educational challenges that today's students are facing.

Keywords

Computers and education, Collaborative computing, Collaborative learning, Web search

Introduction

Collaboration in the search task

one of the most common tasks carried out on the Internet is searching for information. Under a traditional model, this task is conceived as executed by a single user, omitting interaction with other people (Twidale et al., 1997). Because of this, online search tools –search engines plus the browsers used to access them- are mostly designed for users to search individually (Broder, 2002). Education, work or social interaction are some of the many scenarios under which collaboration in the search process happens in our daily lives (Amershi & Morris, 2009); however search engines and browsers cannot handle this characteristic, forcing users to turn to complimentary methods and tools. Examples of this are the use of a single computer, with one user leading the search, and another looking over his shoulder, sharing search results via email, or coordinating joint searches through instant messaging systems (Morris, 2007). The distance between the functionality offered by the technologies we use, and the practices of users searching online for information translates into processes where collaboration is not only not supported but also discouraged by the many obstacles users face when attempting to search online together.

Group information searching and the lack of tools to support it have been studied in recent years. (Amershi & Morris, 2008) identified a series of limitations that emerge when users search online for information together without tools that have been specially designed to promote collaboration. Some of these limitations are:

- Difficulties contributing. There are multiple scenarios under which current search tools foster an environment where group members asymmetrically contribute to the search task.
- Lack of awareness. Dominating group members minimize the contribution of others, reducing the awareness of their ideas and suggestions.
- Lack of hands-on learning. Group members who do not have access to a shared computer's input devices loose the opportunity to gain expertise interacting with search technologies.
- Information Loss. Multiple difficulties emerge when groups try to keep track of their findings.

These problems configure an initial research question; how can the search process be scripted to foster collaborative practices between users when they search online together? A script structures the interaction between individuals and determines collaboration and problem solving logistics (Nussbaum et al., 2009), as well as offering detailed sets of instructions for each part of the activity being conducted (O'Donnell & Dansereau, 1992). Scripting for collaborative searching requires us to distinguish between cooperation and collaboration, as the difference between them is often unclear. Cooperation refers primarily to the division of tasks within a group, where each member is responsible for his own actions, while collaboration is defined as the coordinated work of a group of individuals to solve a common problem together, where all members are responsible for the end result (Roschelle & Teasley, 1995; Dillenbourg, 1999). Cooperation is similar to what factory workers do in an automobile assembly line, where each worker is responsible for carrying out a specific action, and is only worried about completing said action successfully. Collaboration, on the other hand, can be compared to putting together a puzzle, where everyone helps on any part of the puzzle and is responsible for a misplaced piece (Szewki et al., 2011). When applying these concepts to group information search, it is possible to see how cooperative searching is actually a union of individual searches, and doesn't necessarily offer a technological challenge to the tools we use today. On the other hand, collaborative searching faces us with the need to restructure our practices and tools to include the possibility for users to search and build solutions and answers to questions together.

The success of collaborative dynamics in-group work depends on six criteria that have been established in several studies, and were summed up in the work of E. Szewkis (Szewkis et al., 2011). These collaboration criteria are:

- Common goal: a common objective, shared by all the members of the group (Dillenbourg, 1999).
- Positive interdependence: correlation between peers' work, so that the success of each member depends on the work of his teammates (Johnson & Johnson, 1999).
- Coordination and communication: interactions must occur in the right order and at the right time, avoiding the loss of communication and cooperation efforts (Raposo et al., 2001, Gutwin & Greenberg, 2004).
- Individual accountability: each member of the team is responsible before his teammates for the actions he carries out and their consequences (Johnson & Johnson, 1999).
- Awareness: each member of the group can obtain information about the state that the work is in regarding both the group work and his teammates' individual work (Zurita & Nussbaum, 2004).
- Joint rewards: depending on the results of their work, the entire team receives the same evaluation, whether it is a reward or punishment (Zagal et al., 2006).

Additionally, collaborative search presents the challenge of division of labor (the way that the members of a group distribute the workload between themselves). Attempting to reduce unnecessary redundancy users work with parallel search patterns; this can only be achieved successfully through high coordination and awareness of teamwork (Morris, 2008). Faced with this task, strategies that distribute the workload enabling parallel work without affecting awareness of what others are doing must be found.

All of this adds up to the need to develop new search models that support collaborative behaviour among users. Our initial research question can be rephrased as, how can the search process be scripted to help align a group of users under a common goal, augment their positive interdependence, contribute to better coordination and communication, reinforce individual accountability of each member of the group, help them achieve better awareness of their teammates' work and strengthen the division of labor between them when searching online together? The reformulation of the research question purposefully leaves out the criteria of joint rewards because this is external to the actual search process; the reward for a successful or unsuccessful search session depends on the context where this is being carried out and therefore does not correspond to the organic structure of the task of searching online for information.

Collaborative learning and collaborative search

In recent years, collaborative learning (CL) environments have gained importance and notoriety. By collaborating with their peers, students develop important communication and social skills as they learn to carry out multidirectional dialogues and submit their ideas to their classmates' critical analysis (Nussbaum et al., 2009). Collaborative learning allows the members of a group to articulate their points of view and negotiate and exchange ideas; learning is achieved through a process of building knowledge (Infante et al., 2010; Zurita et al., 2005) where students interact with the source of information, their peers, and the teacher.

The Internet, with its growing availability in schools, is shaping up to be the main source of information for students. A large part of the information searches that are carried out within schools are based on group interactions (Large et al., 2002), which is why searching for information has the potential to become a powerful collaborative learning activity. Collaborative search allows students to share not only the results or final products of information searching, but also the process that led to those results (Twidale et al., 1997). Cooperative searching, by merely distributing the workload, encourages bad practices where students use only a fragment of knowledge that they later copy-and-paste to form a greater project; contrarily, collaborative search moves students to work together to build, as a group, the knowledge they need. Collaborative learning environments provide a fertile field where the previously stated research question gains practical applicability; how do collaborative search activities –that follow specific scripting– change the way students work together in groups when searching for information?

Effective collaborative search activities require proposing search models and activity scripting where the user is no longer viewed as an isolated individual, but as an active member of a group. The purpose of this paper is to present a conceptual model of the process of collaborative search and the scripting it requires to be used as a structure for teaching activities that revolve around group search for information and the collaborative building of knowledge. The following section presents a model for collaborative search that is articulated through three levels: a high level understanding regarding the search process that each user faces (abstract model), a general structure for collaborative search activities within the classroom (Macro-Script), and the specific ways in which Macro-Scripts are adapted to specific implementations (Micro-Script). Later we present the CollSearch tool, specially designed computer software that follows the Macro-Script we propose. We also present an empirical study conducted with high school students that evaluate students' outcome when working with the CollSearch tool. The final section presents conclusions and future work opportunities regarding collaborative search as a collaborative learning tool.

Scripting for collaborative searching

The complexity of developing multiuser search models that promote collaboration among the members of a team is possibly one of the reasons that explain the lack of computational tools that help to carry out this task. In order to better understand the challenge, the problem can be divided into two levels: the user's experience when faced with the task of searching (abstract model) and the sequence of steps or stages that a collaborative search activity follows (script). Scripting can be conceived on two levels: on one hand, we have the general structure of the activities (Macro-Script), and on the other we have the concrete steps that must be followed during a collaborative search activity within the classroom (Micro-Script). A Micro-Script is an instruction manual for the teacher and the student that adapts the Macro-Script to the specific subject and context in which the activity is being carried out (Dillenbourg & Tchounikine, 2007). In order to illustrate the difference between both scripts, we can picture a game of chess. The Macro-Script contains the rules of the game that determine the existence of two players that face each other, the goal for each player, the distribution of the pieces on the board, the movements allowed for each piece, the structure of turn-taking in the game, etc. Then a Micro-Script determines the implementation of the Macro-Script. This Micro-Script changes according to the type of implementation; for example, the game can be played with a physical board and pieces, by letter, through a computer simulator, etc. While the Micro-Script can change depending on the support tools that are used and the context of the game, the Macro-Script remains constant because each Micro-Script is an implementation of a game of chess. This allows us to see the logic of the activities and their specific implementations, separately.

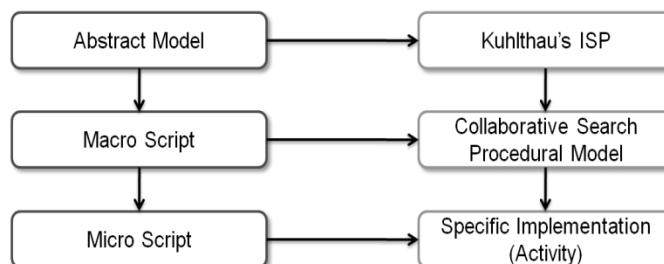


Figure 1. Collaborative search model in three levels

The following model is articulated on the three levels described above (Figure 1). It uses Kuhlthau's Information Search Process as an abstract model of the stages a user undergoes when facing a search task (Kuhlthau, 2010), it defines a procedural model for collaborative search and, proposes the issues that are relevant when transforming both the abstract model and the Macro-Script to a concrete implementation within the classroom, or Micro-Script.

Abstract model

Kuhlthau's Information Search Process (ISP) models the user's experience during the search task (Kuhlthau, 2010); it was initially developed in the 1980s and has been refined and updated since then, becoming a highly influential model (Cronin & Mehro, 2006) that has been used across multiple settings including educational applications through guided inquiry (Kuhlthau et al., 2007). Despite how much the information environment has changed since the first design of the model, it remains a valid way "for describing information behavior in tasks that require knowledge construction" (Kuhlthau et al., 2008). The model offers a general understanding of the different stages that a person goes through during the process of searching for information (Figure 2). Despite the fact that Kuhlthau's ISP is based on the perspective of a single person searching for information, there are studies that show that it would be possible – without major modifications- to apply this model to a group search (Hyldegard, 2009).

Macro-script

In the case of collaborative search activities within a collaborative learning context, we propose a Macro-Script called *Collaborative Search Procedural Model* (CSPM). The model considers the existence of two roles: student and teacher. The student acts as a member of a search team who must collaborate with his peers, search for and contribute new information and document the search process, as well as the results. The teacher is a facilitator of the activity and must monitor each groups' and students' performance to know when and how intervention is required. This model presents the collaborative search activity scripted as a series of steps where the individual process that each student goes through –described in Kuhlthau's ISP- is inserted into a group dynamic where the collaborative atmosphere aims to take advantage of the interaction among peers, so as to reduce negative feelings –uncertainty, frustration, etc.- and boost positive feelings –optimism, confidence, etc. The CSPM proposes decreasing interventions from the teacher, as far as guiding the search process, so it is gradually left in the group's hands as they learn to focus their work. In order to achieve this, the steps that are mainly exploratory are guided by the teacher, while the steps where knowledge is built and documented call for more independent work by the students.

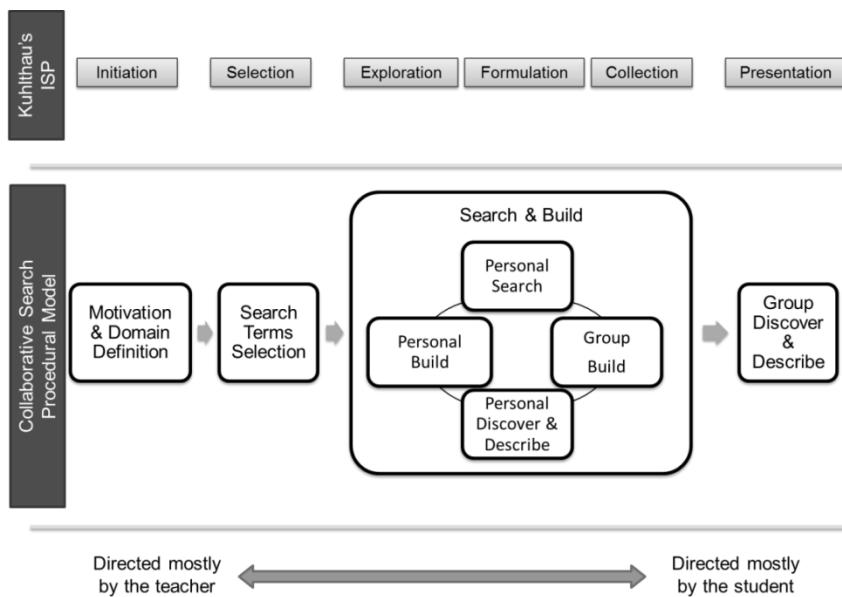


Figure 2. Collaborative search procedural model and its connection to Kuhlthau's ISP

The CSPM's Macro-Script proposes four linear stages: (1) Motivation and domain definition, (2) Search term selection, (3) Search and construction –made up of the sub-stages of personal search, personal build, personal discover and describe, and group build- and (4) Group discover and describe. The structure of the CSPM –including stages and sub-stages- is summarized in the diagram presented in Figure 2. Each stage and sub-stage of the CSPM is defined by a high-level procedural description and by collaboration goals determined according to the criteria laid out in the introduction of this paper (Table 1).

Table 1. Stages of the CSPM

Macro-Script Stage	Description	Collaborative objective
Motivation and Domain Definition	The subject of the investigation, as well as its general objectives, reach and focus must be determined with the intervention of the guide (teacher). Additionally, the rules to be followed during the activity are established, such as the way in which the work will be divided, and what platform or medium will be used to build the final hand-in which could be a written document, a video, a presentation, etc.	A common goal must be established for all students. Rules of coordination and communication must be determined. The common rewards that the students will receive must be made explicit.
Search Term Selection	Lead by the activity guide (teacher) the students suggest key words or queries for the group search, which are shared with all the other students. The facilitator does a brief discussion about query construction and the search tool being used; in-group discussions about the search terms to be used are conducted to help students informally distribute the work.	The collective formation of queries increases each student's awareness regarding others' work (Morris et al., 2006). By establishing an initial work distribution students can avoid redundancy and help establish each student's individual responsibility regarding the activity.
Personal Search	In this stage, each student searches for information independently –using queries related to the keywords and sub-domains assigned in the previous stage. Each result must be filtered, evaluated, and valued.	Personal searches allow students to feel that part of the work belongs to them, increasing their perception of individual responsibility. By ensuring personal processes, we can avoid a single student taking over the work and ignoring others' work, which increases positive interdependence. Parallel work contributes to a distribution of the work without duplicates, while at the same time forcing an increase in awareness, coordination and communication.
Personal Build	The searching users (students) summarize every result that comes up through their web search. They are free to organize and categorize these summaries how they prefer, so they understand the specific contribution that this information makes to the investigation.	
Personal Discover and Describe	The student organizes his personal summary so it is coherent, and builds a macro-structure with the information, following the classification he determined in the personal build stage. In this way, he can articulate his ideas and knowledge before exchanging with his teammates.	
Group Build	Using the results contributed by each member, as well as their respective summaries of key concepts, the information must be reorganized, so as to articulate the entire group's contribution in a first draft of the answer to the initial question. Group building can happen through the reclassification of group summaries under new criteria defined by the group, or by linking ideas from the summaries, so as to create a "map" of the knowledge that the group has built.	The integration of each member's contribution increases positive interdependence and forces students to work in a coordinated manner. Ideas presented by teammates increase awareness regarding others' work. Building a single final presentation that belongs to the entire group –as opposed to belonging to any one student- allows students to better understand why there are joint rewards.
Group Discover and	The members of the group work together to build a final answer to the question that was the	

Describe	object of the collaborative search. This answer includes all the angles that were studied individually, but organized in such a way as to allow the group to articulate and transfer the joint knowledge. In this way, the final result belongs to the entire group, and not any individual member. The format of this answer will depend on what was initially proposed by the guide.
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Following the collaborative search model in Figure 2, each of the stages of the Macro-Script in Table 1 must be implemented through a specific Micro-Script. Determining these instructions requires a series of design decisions that are specific to the implementation scenarios under which the final deployment will be done; because of this, there is no unique Micro-Script for the model.

CollSearch, a software tool based on the CSPM

The CSPM and the Micro-Script that implements it propose a schoolwork situation where a group of students can investigate a certain subject assigned by their teacher, and then collaboratively build a final hand-in. The first two stages of the CSPM, which are mostly directed by the teacher, present the topic and help students learn about query construction and search techniques. The following three stages are individual research phases, where the student finds information that is relevant to the topic, builds his own point of view and knowledge on the matter and prepares to share his results with his teammates. The final two stages allow students to exchange knowledge –fostering learning among peers- and work together to build a final hand-in containing ideas proposed by all the members of the group.

The implementation of the CSPM in a computational tool requires the elaboration of a Micro-Script that transforms each step of the previously presented Macro-Script into a concrete sequence of activities. It also requires a communication and interaction model that allows the members of each group to interact among themselves and with the system, while the teacher monitors each group's progress.

Micro-script for collSearch

Because the CSPM is a Macro-Script, it can be applied to many different scenarios through different Micro-Scripts. CollSearch's Micro-Script establishes a workflow that enables a group research activity within a classroom environment; each step of the Micro-Script is aimed at promoting collaboration between the group's members.

Table 2 shows the implementation of each step of the CSPM through specific sequences of activities that compose the Micro-Script, broken down according to the two roles considered by it: teacher and student.

Table 2. Micro script for CollSearch

CSPM Stage	Specific Micro-Script Instructions	
	TEACHER	STUDENT
Motivation and Domain definition	The teacher introduces the topic of the investigation, explaining its general objectives, reach, and focus. In the computer system, he defines the parameters of the activity and uploads the class list, in order to randomly form groups.	The students interact with the teacher during the introduction of the investigation topic, just as they would during a normal class. In the computer system, each student registers and logs in (Figure 3a), waiting to be randomly assigned to a group.

Search Terms Selection	<p>The teacher asks the students to suggest search terms that pertain to the topic. He receives the students' contributions in the computer system and might add more or delete some if necessary. The teacher must then lead a brief discussion about each search term and how they relate to the topic.</p> <p>Additionally, brief explanations about terms that the teacher considered off-topic (and deleted) can also be useful.</p> <p>During this discussion, the teacher must also address query construction techniques and how queries impact the quality of our research.</p>	<p>Students form groups, as determined by the application. The students must suggest search terms that they believe will cover the domain and focus described in the parameters of the activity. Suggestions are sent to the teacher anonymously. Once the teacher has filtered the terms, each student receives the list of them and a brief in-group discussion must be had to determine an initial work distribution within the group (Figure 3b). This can be explicit (each student is assigned specific search terms) or implicit (where students orally agree on how to distribute the work and the areas in which each one will focus).</p>
Personal Search	<p>The teacher monitors each group's progress using his computer interface. When he detects the need, or a group calls him, he can physically approach them and provide help or guidance.</p>	<p>Each student carries out individual searches. Whenever he finds a useful site, the student can bookmark it, adding extra information like a personal description or evaluation of its contents (Figure 3c). <u>Saved web references are available for revisiting.</u></p>
Personal Build		<p>The student can access his bookmarks and make small annotations about the information he has found (Figure 3d). Each note is a summary of the site's content, and it is stored along with the source's URL.</p>
Personal Discover and Describe		<p>The student organizes the notes he has created, placing them on the Virtual Work Table (Figure 3e) in the order that makes sense to him. He can add hand-drawn pictures and edit the contents of the notes, so as to strengthen his mental outline of the content he is contributing. While the table is a space that is shared by the entire group, in this stage each collaborator works individually, using a space on the table that is separated from his teammates.</p>
Group Build		<p>Students work as a group to organize the information they collected individually. Each student checks the contents of the Virtual Work Table (Figure 3f) complementing his teammates' information with his own knowledge, with the possibility of adding comments to a teammate's notes, checking sources (web references), modifying the contents of the note or the outline. All the notes are reorganized, forming a group outline that expresses the vision and knowledge of all the members of the group.</p>
Group Discover and Describe		<p>A writing student is randomly selected and begins to edit the final document (Figure 3g): he must select the notes from the outline, one by one, send them to the document display and incorporate their contents in a consistent manner; references are automatically added to the paper's bibliography. During the writing process the collaborators who cannot edit the final document become readers; they constantly check their teammate's work and help him, mediating through different communication mechanisms (directly or through the group chat). When all the notes have been used, the writer notifies his teammates that the document is ready for their evaluation. When the document is under evaluation, readers must vote on whether they agree with the result or not. When all the readers agree, the stage and the activity are completed.</p>

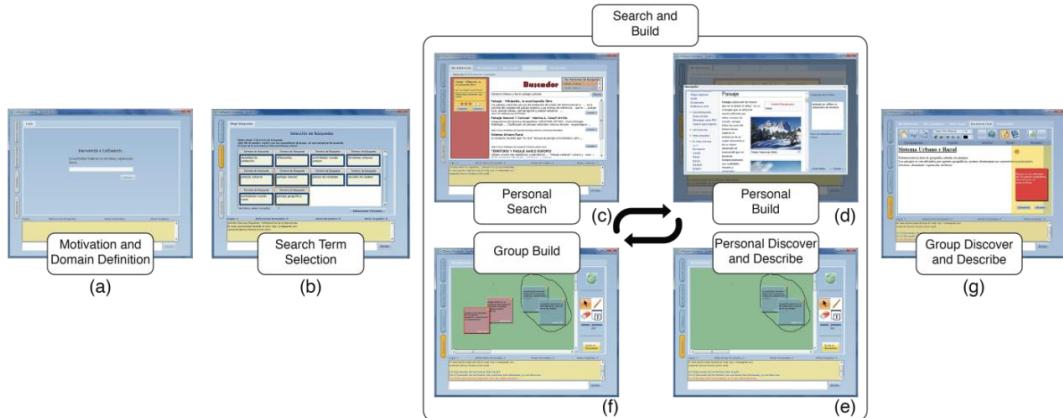


Figure 3. CollSearch interfaces and how they follow the CSPM

Communication and interaction model

One of the complexities involved in the collaboration criteria of Coordination and Communication (Gutwin & Greenberg, 2004), and Awareness (Janssen et al., 2004) is the fact that in order to be updated regarding their teammates' work, students may be constantly interrupted in their own work; this makes it necessary to implement technological support for the CSPM that provides transparent communication mechanisms among the members of the group, i.e., mechanisms that don't interrupt the student's work flow. For CollSearch we determined the communication needs that the system had to fulfill in each stage of the CSPM (Table 3).

Table 3. CollSearch communication needs

Stage	Communication needs	Technological support (See Figure 4)
Motivation and Domain Definition	None	None
Search Terms Selection	Coordination between students to determine an initial work distribution.	Group chat, which is always visible.
Personal Search	Awareness regarding the bookmarks created by other members of the group, the type of information they have gathered and how advanced their work is.	Group chat, which is always visible. “My Teammates” tab, with a summary of the work carried out by others.
Personal Build	Awareness regarding the number of notes created by other members of the team, as well as their content	Group chat, which is always visible. “My Teammates” tab, with a summary of the work carried out by others. Shared Virtual Work Table.
Personal Discover and Describe	Awareness regarding how advanced other members of the group are in building personal summary outlines	Group chat, which is always visible. “My Teammates” tab, with a summary of the work carried out by others. Shared Virtual Work Table.
Group Build	Shared view of the outline or conceptual map that gathers the group’s ideas	Group chat, which is always visible. “My Teammates” tab, with a summary of the work carried out by others. Shared Virtual Work Table.
Group Discover and Describe	While one student writes the essay, the rest must be able to view what he is writing, offer feedback, give additional information, etc.	Group chat, which is always visible. Shared Virtual Work Table. Interface that allows students to view the Final Document.

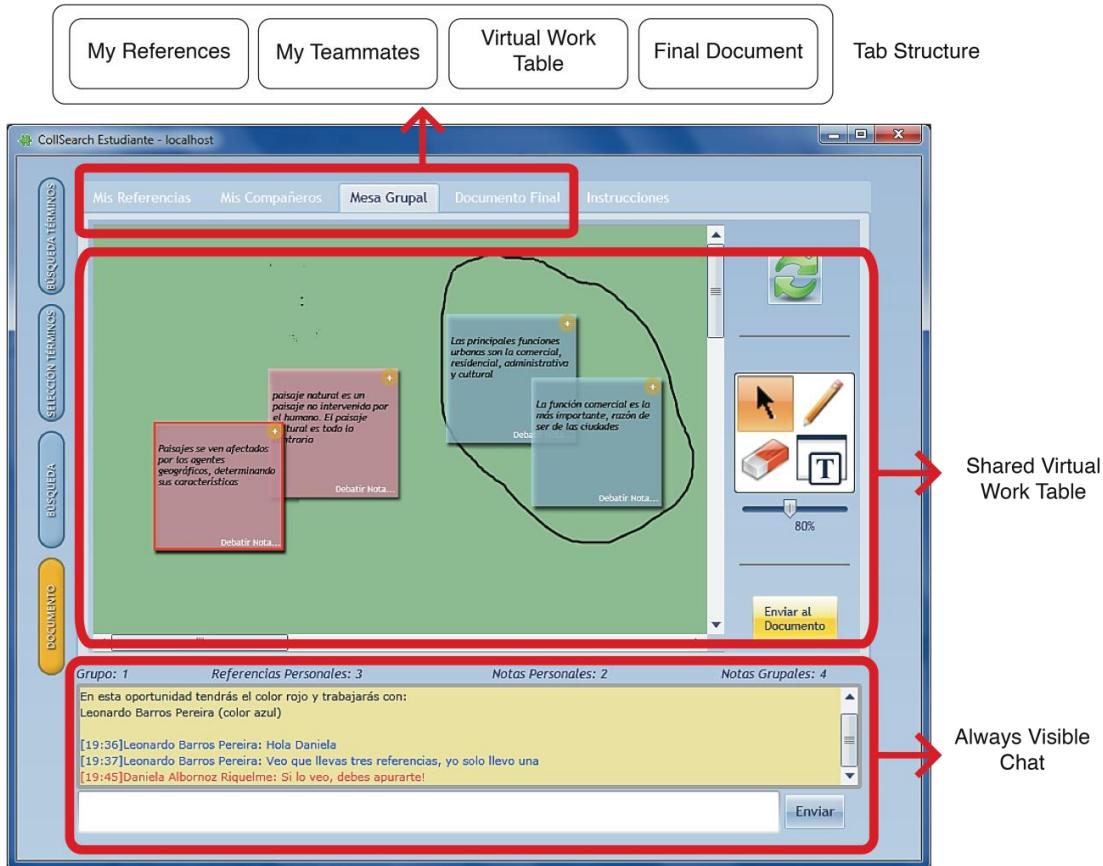


Figure 4. CollSearch's communication support and tab structure

Empirical evaluation

To evaluate the impact that the CollSerach tool has on students' work, we conducted an experimental trial with 60 students from the eleventh grade of a private non-government supported high school in Santiago, Chile.

Method

The activity was part of an English as a second language course and asked students to write a letter to the International Olympic Committee (IOC) nominating Santiago, Chile as the host city for the 2024 Olympic Games. Students were asked to include a minimum of three of the following topics in their documents: Santiago's sports infrastructure, Santiago's hotels and accommodation infrastructure, Santiago's crime rate and safety, Santiago as a tourist attraction, Santiago's transport system, or Santiago's climate. The goal was for them to write in English a compelling argument that would convince the IOC to consider Santiago as a possible host city.

Students were randomly split into groups of 3 and then each of the 20 groups was randomly assigned to one of the following independent activities:

- Control Group: Each student was given access to a personal computer with an internet browser and word processing software. Written instructions were provided and each group was free to organize their work in whatever way they chose. The activity facilitator (teacher) conducted the introduction to the topic and an initial search term discussion (similar to the one the CSPM considers). Later during the activity, the teacher was available to answer questions and guide students through the activity if they asked for her help.

- Experimental Group: Each student was given access to a personal computer with the CollSearch tool. A week before the activity took place, students assigned to this group had an initial 90 minute introduction to the tool and worked in a preliminary activity with a completely different topic and different groups than the experimental session. This initial activity was meant to teach students how to use the CollSearch tool and control for any changes in performance between the experimental and control groups that could be explained by the fact that the CollSearch tool was unknown to students while the browser and word processing software used by the control group was not. During the experimental activity, students were given the same set of written instructions given to the control group students. The activity facilitator (teacher) was available to answer questions and guide them through the activity if they asked for her help.

Each group was given 90 minutes to complete the activity and had to hand in only one letter per group. After they had done this, they had to access an online form where each student was asked to rewrite their letter according to what they remembered from their group's work; during this phase of the activity students were forbidden to interact with each other and no longer had access to the document they had built as a group. The purpose of this second part of the activity was to evaluate how much of the group work had each student appropriated by participating in the group work. An external teacher who did not know which documents belonged to the experimental or control groups conducted a blind evaluation of each of the groups' work. The evaluation measured the overall quality of the letter considering the groups' argumentation and use of facts. A second evaluation was then conducted in which the external evaluator was asked to assess how each individual letter compared to the group's letter; this was done by comparing how much of the information contained in the group's work was reflected in each individual letter. The external evaluator assigned a percentage from 0% to 100% to each individual letter according to how complete it was compared to the group's letter. This meant that any individual letter that contained as much (or more) information than the group's letter would be assigned a 100%, independent of the first evaluation that measured the overall quality of the group's letter.

Results and discussion

Table 4 shows the results of the experimental evaluation of the group work and the comparison between the individual and group letters.

Table 4. Group work evaluation

Percentage of accomplishment of the activity's objectives	p	Percentage of the group work reflected in the individual work	p
Control Group	87%	0.0064	61%
Experimental Group	99%		77%

Results show a statistically significant difference between the performance of the control and experimental groups. The evaluation of the level of achievement of the activity's goals raises when students work using CollSearch instead of freely choosing their work methodology (Cohens'd=1.24). When each student's individual work is compared to their group's work, there is a drop between the amounts of information that the group incorporates into their work versus the information that each student is able to recall when working individually. Despite this being true in both groups, there is a statistically significant difference between the experimental and control groups; students who followed the CSPM script within CollSearch can individually recall more information from their group's work than students that could freely choose their group's work methodology (Cohens'd=0.63).

The differences observed between the control and experimental groups can be explained by the fact that the CSPM fosters collaboration by forcing students to be aware of their teammates' work and to build their final answers together. The activity facilitator observed that most of the students from the control group chose to work in cooperative ways in which each student was responsible for one part of the letter, and then the final document was built copying and pasting each part together; CollSearch through the CSPM prevents students from doing this by forcing them to discuss as a group their work and to build together their final document. This might also explain why students from the experimental group are able to recall more information from their group's work than students from the control group; instead of simply giving a chunk of text to their group's work, CollSearch made them be aware of their teammates' research and contribute their work in a way that appropriately fit their group's final document.

Conclusions and future work

The tools we use today to search the Internet do not offer the possibility for groups of users to work collaboratively. The articulation of Kuhlthau's ISP with the macro and Micro-Script structure proposed by the Collaborative Search Procedural Model is a first approximation to supporting collaborative search practices.

Students who face collaborative search activities while following the CSPM when compared to those who can freely determine their work methodology show better appropriation of their group's work. Empirical evaluation shows that the CSPM increases students' performance and improves the overall quality of their work. Future work must be conducted to understand the impact of systematically using CollSearch as a collaborative learning tool and to study how the observed differences change over time as students and teachers better appropriate the model. An exploration of how different Micro-Scripts and implementations of CollSearch might have bigger or smaller impacts on student performance might also provide further insight on the ways in which the CSPM can have a positive impact on collaborative learning activities. Additionally, from a technical point of view, instead of being built from scratch, new versions of CollSearch could be built using previously existing online tools mashed-up into a unified tool.

Finally, it is important to note that Collaborative Search is a scarcely explored and emerging research field; the approach followed in the project presented in this paper is one of many possible alternatives. The Program for International Student Assessment (PISA) has emphasized the importance of the collaborative component, and starting in 2015 it will measure the capacity and willingness of students to solve problems through interaction among themselves (Davidson, 2012; De Jong, 2012); because of this, we encourage the computer science research community to explore other models that promote collaboration in the search task. Additional elements that must be addressed in future work are the dangers of over-scripting (Dillenbourg, 2002). Scripts provide the necessary scaffolding to enable users to effectively collaborate, but when the overhead introduced by following specific Micro-Script instruction sets surpass the benefits of the new work dynamics, users' performance and throughput drops. Finding strategies to build effective macro and Micro-Script structures is a challenge the community must face through more empirical investigations. Future work must focus on ways to prevent over-scripting and on how to balance the need for a structure to guide activities and the need for students to be able to determine the structure of their workflow. Although this paper presents empirical evaluation conducted with high school students, there are multiple educational settings in which collaborative search can prove useful to improve student outcomes; the use of CollSearch and the CSPM in academic and university settings provides a fertile field to explore in future work.

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