PEL
Pensamiento Educativo. Revista de Investigación Educacional Latinoamericana
2019, 56(2), 1-19

Pontificia Universidad Católica de Chile
Facultad de Educación

Relationship Between Types of Information Problems on the Internet, Processes, and Results

Relación entre tipos de problemas de información en Internet, procesos y resultados

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Abstract

Despite the wide use of the internet for learning, little is known about the relationship between the type of problems, search actions, and results achieved by students. To better understand this relationship, an investigation was conducted with 40 university students who solved 15 information problems of different levels of difficulty. During the students' problem-solving process, the think aloud protocol was used. The resulting data were coded to characterize the search actions and the answers were scored. The analysis was based on mean difference tests and correlations between actions and general results and by levels of difficulty. The results show that the students' performance is not related to the total number of actions, but it varies in a way that is inversely proportional to the difficulty of the problem and that it is proportional to the difficulty. However, the distribution of the actions in the internet search stages is heterogeneous, since it depends on the level and type of difficulty of the problem. These results contribute to understanding the process of solving information problems of different types, showing the need to analyze each stage considering the difficulty of the problems. Likewise, they provide guidelines for the design of problems according to the expected learning.

Keywords: digital competences, information problem solving using the internet, internet search.

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Este estudio fue financiado por la Comisión Nacional de Investigación Científica y Tecnológica (CONICYT) de Chile, a través del proyecto FONDECYT 1151044 y el Programa Formación de Capital Humano Avanzado a través de la beca 21140227 para el Programa Nacional de Doctorado 2014

ISSN:0719-0409 DDI:203.262, Santiago, Chile doi: 10.7764/PEL.56.2.2019.4

Resumen

A pesar del amplio uso de Internet para aprender, se sabe poco respecto de la relación entre el tipo de problemas, las acciones de búsqueda y los resultados que logran los estudiantes al utilizarla. Para comprender mejor este vínculo, se realizó una investigación con 40 estudiantes universitarios que resolvieron 15 problemas de información con distintos niveles de dificultad. Durante el proceso se utilizó el protocolo de pensamiento hablado, en tanto que los datos resultantes fueron codificados para identificar las acciones de búsqueda y las respuestas fueron puntuadas. Se hicieron análisis usando pruebas de diferencia de medias y correlaciones entre las acciones y los resultados generales y por niveles de dificultad. Los resultados muestran que el desempeño de los estudiantes no se relaciona con el total de acciones, pero varía de manera inversamente proporcional a la dificultad del problema y que el número de acciones es proporcional a su dificultad. Sin embargo, la distribución de las acciones en las etapas es heterogénea, pues depende del nivel y del tipo de dificultad. Estos resultados aportan a la comprensión del proceso de resolución de problemas de distinto tipo, mostrando la necesidad de analizar cada etapa en función de la dificultad implicada, al mismo tiempo que entregan lineamientos para el diseño de problemas según el aprendizaje esperado.

Palabras clave: búsqueda en Internet, competencias digitales, resolución de problemas de información en Internet.

Presentation

The internet has become one the main sources of information used by young people to study, including access to data (facts, dates, and definitions), content (articles, reports, etc.), literature (books), and news of various kinds, and all in a variety of formats (text, audio, and video).

However, various studies have shown that young people do not have the digital skills required to conduct efficient and effective searches (Frerejean, Velthorst, Van Strien, Kirschner & Brand-Gruwel, 2019; McGrew, Smith, Breakstone, Ortega & Wineburg, 2019; Organisation for Economic Co-operation and Development, OECD, 2015; Rieh, Collins-Thompson, Hansen & Lee, 2016; Van Deursen & Van Diepen, 2013). As a consequence of this, students fail to take advantage of the potential of the internet to learn (McFarlane, 2019), making only basic use of the resources that it offers.

Similarly, other research has demonstrated that teachers, although they have the necessary skills to assess, select, and present information using digital tools, do not always show the skills to guide students during the search for information on the internet (Claro et al., 2018), in addition to the fact that they use internet as if it were an encyclopedia, since they basically ask students to search for facts, definitions of concepts, or resources such as texts, maps, or images (Hinostroza, Ibieta, Claro & Labbé, 2016; Ibieta, Hinostroza, Labbé & Claro, 2017). Moreover, it is common for teachers to fail to define the type of information sources that students should use, the amount of sources required, and how to assess the quality and relevance of the information found, among other issues (Tallvid, 2016; Van Deursen & Van Diepen, 2013).

In order to address this problem, research has focused on better understanding the search process conducted by students (Frerejean et al., 2019; Hinostroza, Ibieta, Labbé & Soto, 2018; Brand-Gruwel, Wopereis & Walraven, 2009) and understanding the effects generated by search tasks with different characteristics (for example, varying degrees of difficulty).

However, little research has been done on the relationship between the characteristics of information problems, search actions, and the results achieved by students using the internet.

In this light, the question that this study sought to answer was: What is the effect that different types of internet information problems have on the search process and on the results obtained by the students? The results of the study are expected to provide evidence that will guide the design of information problems in the context of teaching activities that are in accordance with the objective of learning and/or developing digital skills.

Related literature

With respect to the process of solving information problems on the internet, a set of models has been defined to search for information on the web in general and for solving information problems in particular (e.g., see Caviglia & Delfino, 2016; Dinet, Chevalier & Tricot, 2012; Kuhlthau, 1991; Marchionini, 1995; Brand-Gruwel et al., 2009). These models agree in terms of structuring the process of solving information problems on the internet in five stages:

1. Define the information problem.
2. Select the search terms.
3. Scan and assess the list of results.
4. Assess the quality of the website content.
5. Synthesize the information in a product (Brand-Gruwel et al., 2009).

However, as shown by Hinostroza et al. (2018), these stages do not occur sequentially and, in many cases, they depend on the characteristics of the search problem to be resolved.

Using this search model as a framework, the main difficulties students face when resolving information problems on the internet are the following:

A. Define the problem: Weak ability to extract key pieces of information and identify different elements of the problem (Frerejean et al., 2019; OECD, 2015).

B. Formulation of the search: Use of search terms extracted directly from the statement, which produces queries that are longer and semantically more general (Freeman, Caldwell, Bennett & Scott, 2018; Monchaux, Amadieu, Chevalier & Mariné, 2015; Sanchiz et al., 2017).

C. Assessment of content: Difficulty in assessing the reliability, relevance, and quality of websites (Brand-Gruwel, Kammerer, Van Meeuwen, & Van Gog, 2017; Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2014; Freeman et al., 2018; McGrew et al., 2019; Walraven, Brand-Gruwel, & Boshuizen, 2013).

D. Assessment of website: Review of only the first search results without evaluating the rest of the websites displayed on the results page (Gwizdka & Bilal, 2017; Rieh et al., 2016).

E. Preparation of response: Copy and paste ready responses that are found on the internet (Dias & Bastos, 2014; Skaar, 2015).

As regards the problems, based on the theoretical framework associated with problem solving, Jonassen (2000) argues that that they have three main characteristics: structuredness, complexity, and abstractness, which refer to the formulation of the problem, which is generally associated with different degrees of cognitive demand of the task. However, when it comes to problems involving searching the internet, it is also necessary to consider the complexity of the search and the availability of information sources or complexity of the problem topic (Wildemuth, Freund, & Toms, 2014).

As regards the structuredness, complexity, and abstractness, Wildemuth, Kelly, Boettcher, Moore, & Dimitrova (2018) showed that the most important attribute is the cognitive complexity of the task, which is typically associated with the revised Bloom taxonomy (Anderson & Krathwohl, 2001). Specifically, the authors stated that more complex tasks are associated with a greater number of reformulations of the search. In addition, Greene, Copeland, Deekensm, & Yu (2018) demonstrated that tasks that require more complex cognitive processes (for example, understanding), are associated with a higher frequency of self-regulated learning actions, particularly with planning and monitoring of the activities. On the other hand, Jansen, Booth, & Smith (2009) showed that students performed simpler searches with problems of minor and major cognitive difficulty (shorter search expressions, fewer unique search terms, fewer pages visited, and shorter duration of the search) than for those of intermediate difficulty. By contrast, Sendurur, Efendioğlu, Senturk, & Caliskan (2019) found that students conducted more searches and visited more pages when solving problems of greater difficulty.

In this regard, Walhout, Oomen, Jarodzka, & Brand-Gruwel (2017), evaluated the influence of the task complexity in different search behaviors, concluding that in the cause-effect tasks, the students carried out more actions associated with the formulation of the search and used fewer words taken directly from the problem, while in the simplest problems the students used fewer search words than for the most complex problems. Likewise, Athukorala, Głowacka, Jacucci, Oulasvirta, & Vreeken (2016) found that for the simplest problems, students used longer queries than for more complex problems, which would be caused due to the accuracy of the search objective.

As regards the evaluation of websites, the results produced by Walhout et al. (2017) show that for problems of greater complexity, the students spend less time assessing the list of results and select the first link from the list of results more quickly than in the cause-effect tasks. However, the results obtained by Athukorala et al. (2016) demonstrate that in exploratory tasks—which generally have greater cognitive complexity, since their objective is mainly to acquire knowledge or conduct research—students review the list of results more frequently than for the simpler tasks (for example, in searching for facts).

Meanwhile, the complexity of the subject is associated with the previous knowledge of the users in the search process (Brand-Gruwel et al., 2017; Wood et al., 2016). Research has shown that non-expert searchers tend to extract search words from the sentence, generating longer and more general searches (Sanchiz et al., 2017), use complete sentences or less relevant terms (Monchaux et al., 2015), or use only one word to conduct a search (Freeman et al., 2018), producing more ambiguous, general, or irrelevant results (Lei, Lin & Sun, 2013).

Regarding the association between the characteristics of the problem and student performance, the results of the study by Walhout et al. (2017) demonstrate that students obtain the worst results for the most complex problems, and that they do significantly better for the simplest ones (for example, those on cause and effect).

On the other hand, Gadiraju, Yu, Dietze, & Holtz (2018) found that students learn more when they search for information regarding topics they are not familiar with, but the authors did not find a relationship between search actions and student performance.

Finally, regarding the relationship between the search actions and the performance of the students, Aula, Khan, & Guan (2010) demonstrated that the students who managed to solve the problems with the greatest success made fewer search formulations (query) and spent less time evaluating the websites on the search results page. On the other hand, Argelagós & Pifarré (2012) found that better performance is associated with a greater frequency of related actions to define the problem and create products. In this sense, the results of previous research show that the relationship between actions and performance is more dependent on the stage of the search.

Method

Study design

In the framework of a socio-constructivist perspective, the study was based on a non-experimental research design of a cross-sectional type. In order to do this, a group of subjects were presented with a set of information problems with different levels of difficulty, which had to be solved individually with internet support in a room equipped to solve information problems.

Participants

The participants in this study were first year students from a public university in southern Chile. The sample consisted of 40 individuals, who were intentionally selected considering the following criteria: in the first year of university, between 18 and 21 years of age, and Chilean. The participants were 18 years old on average, they were mostly women (27), and were studying degrees the faculties of Social Sciences (35%), Engineering (33%), Medicine (20%), and Legal Sciences (12%).

Data collection techniques

In order to collect the data, the concurrent thinking protocol was used (Ericsson & Simon, 1980; Gerjets, Kammerer, & Werner, 2011; Van Someren, Barnard, & Sandberg, 1994). This technique consists of training participants to verbalize the information they retain in their short-term memory (Ericsson & Simon, 1980). In particular for this study, the focus was on identifying the cognitive processes of the students during the resolution of information problems on the internet (Oh & Wildemuth, 2009), and thus avoiding the appearance of deceptive reports on the actions performed (fabrication), or rather, the description of the shortest path to find the correct answer (Branch, 2000; Brand-Gruwel et al., 2017; Oh & Wildemuth, 2009).

To do this, 15 internet information problems were designed, which addressed four topics: life expectancy, general arts, cinema, and drugs. The problems were of increasing difficulty and were designed considering problems in which facts had to be found, explanations or definitions or had to be searched for and interpreted, and information had to be sought to compare situations or analyze a problem (Annex A). The problems were tested in a pilot sample with five students and they proved suitable for the age group.

Analysis

Regarding the protocol of thinking aloud, the analysis unit was defined as the expressions which the students used to explain what they tried to do, what they felt, remembered or reflected, and how they justified certain actions or decisions associated with the information problem-solving process. After coding the units, four stages of analysis were performed, combining directed and conventional content techniques (Hsieh & Shannon, 2005). First, the units were classified into one of the five stages of the process of solving internet information problems described above. Secondly, the units classified in each process were analyzed and grouped by types of activity (e.g. understanding the requirements of the problem, implementation of search strategies, keyword selection, etc.). Thirdly, the expressions grouped by each type of activity were analyzed and categories were defined that reflected different actions verbalized by the students while thinking aloud (the results of this analysis are available in Hinostroza et al., 2018). Lastly, the categories were reviewed and actions were selected that, according to the available literature, represent unwanted behaviors, such as copying and pasting the problem statement, copying and pasting the response, etc., which were grouped into a new category.

Based on this procedure, 9,330 expressions were identified from the students associated with the process of solving information problems. Of these, 7,695 (82.5%) were actions related to the different stages of solving information problems described by Brand-Gruwel et al. (2009), which refer to: defining the problem, formulation of the search, assessment of content, assessment of the website, and preparing the answer. In addition, 1,283 (13.8%) search actions defined as problematic by the literature were identified and grouped under the category "Undesirable". Finally, 352 (3.8%) related to monitoring the problem-solving process that the students carried out.

With this universe of actions the following variables were calculated for each subject and problem solved:

A. Total actions carried out by each subject in the 15 information problems.

B. Total actions carried out by each subject in each of the information problems.

C. Total actions carried out by the subject at each stage of the search process.

D. Distribution of the actions carried out by the subject in each of the stages for each of the problems.

This last variable was calculated to reduce the effect of the tendency of each subject to verbalize.

The correction of the information problems considered the construction of a category for each of them, which were scored on a scale of 0 to 4, where 0 corresponds to *Did not answer the question*; 1 to *Not achieved*; 2 to *Partially achieved*; 3 to *Achieved*; and 4 to *Fully achieved*. All the problems were corrected by two evaluators and, in the cases in which there was a discrepancy in the application of the scoring criteria, one of the researchers assessed the discrepancy and assigned the final score to the answer. The score obtained by the students was categorized by adding and subtracting a standard deviation from the average of the students' results on the problems (Low> 1.84; Regular 1.85 – 2.83; High <2.83).

The performance analysis included the level of difficulty of the information problem, while the difficulty considered three criteria (Annex B):

A. Cognitive demand, which corresponds to the cognitive processing requirements to solve the problem using the revised Bloom taxonomy as a framework (Anderson & Krathwohl, 2001).

B. Difficulty of the search, which corresponds to the number and type of internet searches involved in the problem-solving process.

C. Complexity of the topic, which corresponds to the familiarity of the topic addressed by the problem (linked to the student's prior knowledge of the topic) and the amount of information available on the internet on that topic.

Each of these criteria was classified as Low or High (1 and 2, respectively), in order to obtain a discrete combination of difficulty levels. To define the difficulty of the problems, a score was assigned to each criterion and then the scores were added up, obtaining values between 3 and 6. On the basis of this, each problem was categorized according to its difficulty as: Easy (sum = 3; 3 problems), Intermediate (sum = 4; 6 problems) and Difficult (sum = 5 or 6; 6 problems).

In order to investigate the difference in the number of actions and the difficulty levels of the problems, we used the ANOVA test of repeated measures. The same analysis was used to evaluate the difference between the scores obtained by the students on the same problems and on the distribution of actions according to the difficulty of the problem. On the other hand, the one-way ANOVA test was applied to determine whether there were differences between the number of actions per question according to the difficulty of the problem and the students' average result. Finally, in order to evaluate the difference in the distribution of actions by type of difficulty (high-low cognitive; high-low search, and high-low topic), the Student's *t*-test was applied for related samples. The relationship between the number of total actions and the average performance was analyzed with Pearson's *r* test.

Procedure

The invitation to participate in the study was disseminated among the students through the degree course directors and lecturers at the selected university. Those interested attended informational meetings in which they were informed of the objectives of the study and the activities that their participation would involve. Those who agreed to participate signed an informed consent previously approved by the university's Scientific Ethics Committee. Participation was voluntary, anonymous, and confidential. Before beginning the procedure, the participants took part a training session in the technique of thinking aloud, after which they individually responded to the series of instruments during January 2015 and January 2016, in all cases having face-to-face support from research assistants. During each session, the research assistant made sure that the students continued verbalizing their thoughts. All of these verbalizations were recorded and then transcribed, to be analyzed later.

The solution of the problems was carried out in four sessions, which took place over a period of three weeks. In each session the students were asked to solve between three and four information problems using the internet. The information problems were presented to the students following the same sequence and had a maximum duration of 80 minutes per session.

Results

Information problems and search processes

The results show that there are significant differences in the number of actions (search process) that students carry out when they solve problems with different levels of difficulty $F(2, 78) = 64{,}469$, $p < 0.05$. Specifically, when students solve difficult problems they carry out more search actions ($M = 19.60$, $SD = 8.8$) than when they solve problems of intermediate difficulty ($M = 14.556$, $SD = 6.5$) and easy difficulty ($M = 9.4$, $SD = 5.6$).

The distribution of actions in the different stages of searching for information shows that the highest proportion of actions is associated with the stage of defining the problem (24.8%), followed by evaluation of the content of the websites the subjects visit (23.6%), the formulation of the search (16.7%), the set of actions classed as "undesirable" (13.8%), and the preparation of the response to the problem (10.9%). Finally, students devote only 6.5% of their actions to assessing the websites they will use and 3.8% of the actions to monitoring their progress in solving the problem. As regards the distribution of the actions at each stage of the search according to the difficulty of the problems (Figure 1), we can observe that, for difficult problems, students perform more actions related to the formulation of the search than for easy and intermediate problems. Likewise, for problems of intermediate difficulty, they carry out more actions than for easy ones. It can also be seen that students conduct fewer content assessments for difficult problems than for intermediate problems, although they carry out more monitoring actions.

Meanwhile, for easy problems the subjects conduct more site evaluations than for difficult and intermediate problems, although they carry out fewer actions associated with preparation of the response and unwanted behaviors than with the difficult and intermediate problems.

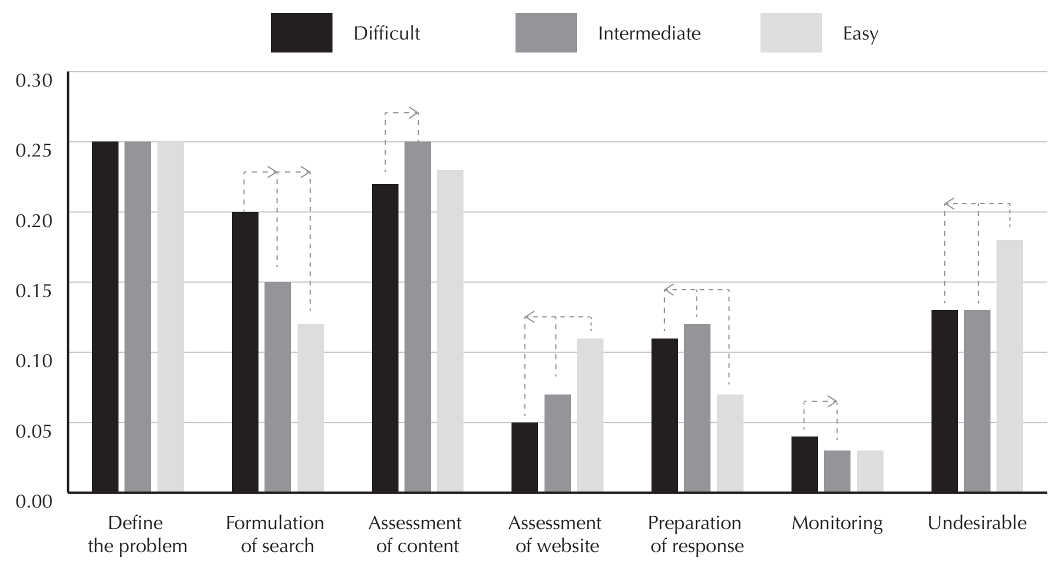

Figure 1. Distribution of search actions depending on problem difficulty.
Note: Arrows denote significant differences.
Source: Prepared by the authors.

As regards the distribution of actions by the difficulty, Figure 2 shows the distribution according to the cognitive demand of the problem. As we can see, for problems with high cognitive demand, the students carry out more actions associated with the formulation of the searches, but fewer assessments of the websites and content, and perform more actions associated with preparing their answers than for problems of low complexity.

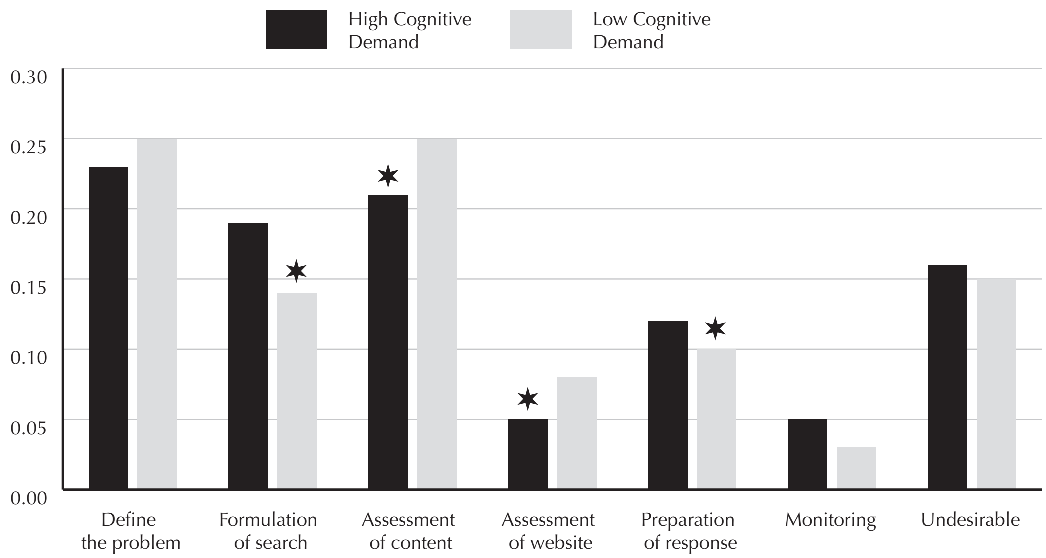

Figure 2. Distribution of actions depending on cognitive demand of the problem.
Note: The asterisks denote significant differences.
Source: Prepared by the authors.

Meanwhile, Figure 3 shows the distribution of actions according to the search difficulty for the problem. We can see that the students carry out more actions associated with defining the problem and formulating the search for problems of high difficulty than for those of low difficulty. However, they perform fewer actions related to the assessment of sites and content, as well as carrying out less work to prepare their responses. Finally, for the problems for which the search is more difficult, they carry out a larger amount of undesirable actions.

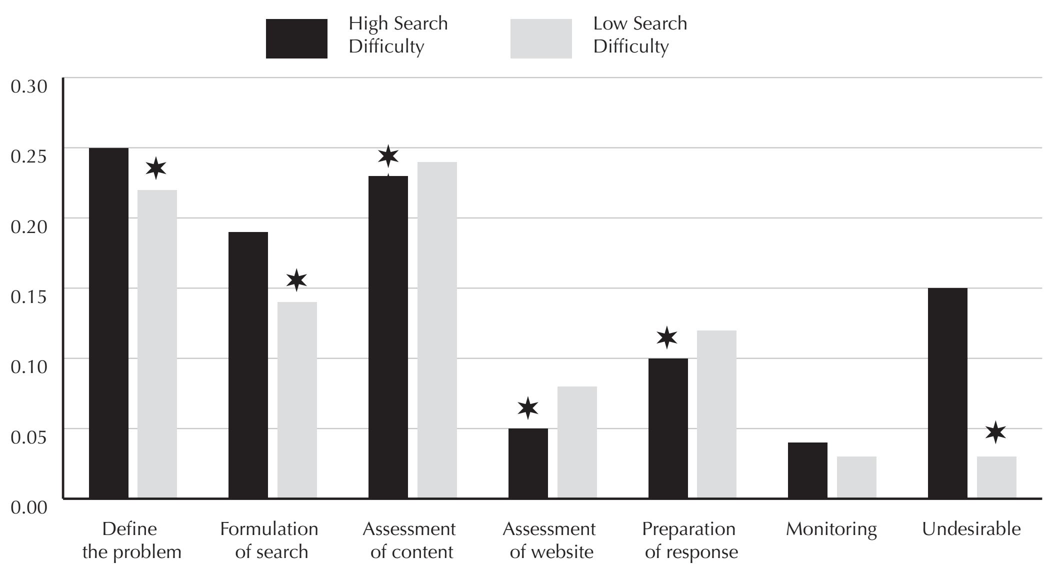

Figure 3. Distribution of actions depending on search difficulty of the problem.
Note: The asterisks denote significant differences.
Source: Prepared by the authors.

Lastly, and in relation to the distribution of actions depending on the complexity of the question, in Figure 4 we can observe that for problems that deal with more complex topics, students perform fewer actions related to the assessment of the content, but they devote more effort to preparing the responses and monitoring the activities they carry out.

It is interesting to note that, when solving problems on more complex topics, students carry out fewer undesirable actions than when solving problems on simpler topics.

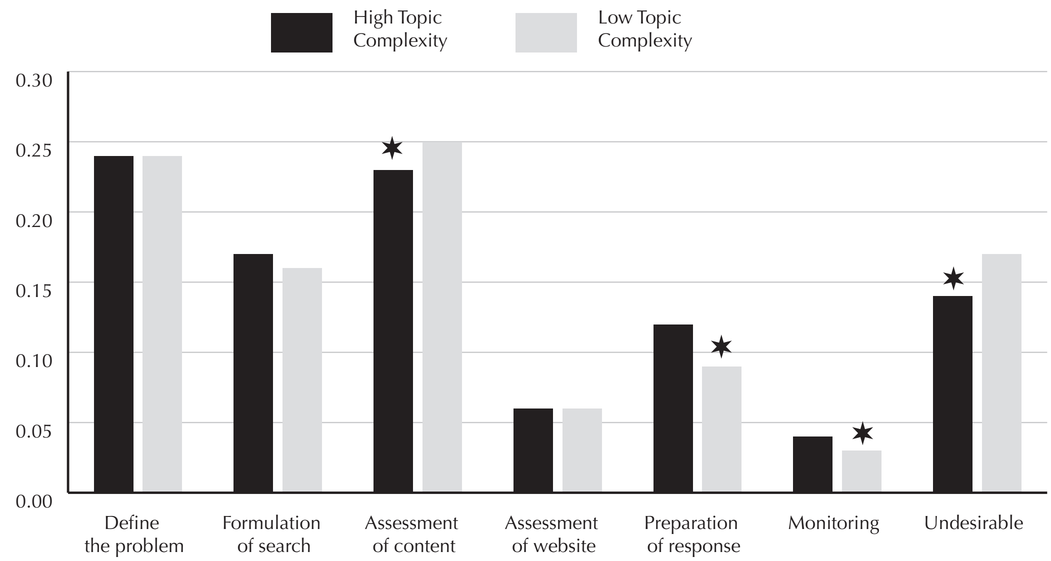

Figure 4. Distribution of actions depending on complexity of the problem topic.
Note: The asterisks denote significant differences.
Source: Prepared by the authors.

Information problems, the search process, and student performance

The results show that there are significant differences in student performance to solve problems with different levels of difficulty $F(2, 78) = 73{,}946$, $p < 0.05$. In particular, when solving difficult problems the students score significantly lower ($M = 1.88$, $SD = 0.56$) than when solving problems of intermediate difficulty ($M = 2.38$, $SD = 0.56$) and easy difficulty ($M = 3.17$, $SD = 0.76$).

When analyzing the results according to the type of difficulty, the students perform significantly more actions and obtain significantly lower scores when solving problems with greater cognitive demand, search complexity, and difficulty of the topic (Table 1). On the other hand, no significant correlations were found between the number of actions for the problems depending on the type of difficulty and the scores obtained by the students on those problems.

Table 1. Score and number of actions by type of difficulty of problems

	Average score					Average Nº of actions				
	High		Low			High		Low		
Type of difficulty	M	SD	M	SD	*p*	M	SD	M	SD	*p*
Cognitive demand	2.06	0.52	2.52	0.60	0.00	19.07	8.80	13.19	5.94	0.00
Search difficulty	2.08	0.61	2.50	0.53	0.00	19.45	8.89	12.95	5.80	0.00
Topic complexity	2.04	0.58	2.68	0.54	0.00	16.87	6.81	14.03	7.02	0.00

Source: Prepared by the authors.

No significant relationship was found with respect to the relationship between the total number of actions and the average score obtained by the students ($r = 0.14$). However, when comparing the number of actions by the difficulty level of the problem and by the category of the scores that students obtain, we observed that for easy problems, students who obtain poor results perform significantly more actions than students with regular results.

Discussion

This study was intended to understand the effect that different types of information problems have on the internet search process carried out by university students and the results they obtained.

Generally speaking, and in agreement with other research (Gadiraju et al., 2018), the results show that there is no relationship between the frequency of search actions and the performance of the participants. However, it is interesting to note that students who obtain lower results carry out significantly more actions than those who obtain regular results when solving easy problems. These results are not consistent with those of previous studies (Argelagós & Pifarré, 2012; Aula et al., 2010) that have indicated that the relationship between the number of search actions and performance changes depending to the search stage and, therefore, the fact that in this case the difference is in the total number of actions throws up new questions and highlights the importance of considering the difficulty of the problems when designing research. This result may show that underperforming students, when they do not find the answer quickly, apply trial and error techniques to continue searching.

On the other hand, when the results are analyzed in terms of the type of complexity of the problems, we observe that problems that are more difficult require more effort on the part of the students (more search actions) and they achieve lower performances. In terms of performance, these results are in line with those of Walhout et al. (2017), but the association between the difficulty of the problem and the number of actions contradicts the results of Walhout et al. (2017) and Jansen et al. (2009), who indicate that for problems of minor and major cognitive difficulty, students perform fewer search actions than for those of intermediate difficulty. In this regard, these results are more logical, since students would be expected to carry out more actions to solve more difficult problems.

As regards the search actions, in each of the stages of the process to solve information problems, we observed that, unlike what has been reported in other studies (Frerejean et al., 2019; OECD, 2015), students devote a large proportion of actions to the stage of problem definition, particularly for problems that involve greater search difficulty. These results point in the expected direction, as it is reasonable for students to spend more time understanding the problem when facing a greater challenge.

In terms of formulation of the search, as has been shown in other research, students devote more actions to this stage for problems that have a higher cognitive demand (Wildemuth et al., 2018) and search difficulty (Walhout et al., 2017), which shows the need to explore different search options to resolve more difficult problems (Sendurur et al., 2019).

Considering the assessment of content, it is interesting that students devote a significant proportion of their actions to this stage, particularly for problems of intermediate difficulty, which tends to corroborate the results of Jansen et al. (2009). However, when analyzing these results according to the type of difficulty, we observe that, regardless of the type of problem, the proportion of actions is lower than for problems of high difficulty, especially those with higher cognitive demand. This is interesting and could show that, when faced with more difficult problems, students tend to be less selective and apply fewer criteria to assess the reliability, relevance, and quality of websites, as other researchers have suggested (Brand-Gruwel et al., 2017; Fraillon et al., 2014; Freeman et al., 2018; Walraven et al., 2013).

The proportion of actions carried out by students associated with the assessment of websites is low, especially for problems with high cognitive demand and greater search difficulty. This supports the previous results that suggest that students devote little effort to this task, since they only review the first search results (Gwizdka & Bilal, 2017; Rieh et al., 2016). This reveals the need to emphasize this aspect when teaching search strategies to students, due to the high degree of heterogeneity of the quality of the websites available on the internet.

The process of preparing answers follows a similar pattern to the appraisal of content, since students devote a greater proportion of actions to problems of medium difficulty than to difficult and easy ones. It is interesting to examine this behavior considering the types of difficulty, since the participants devote a greater proportion of actions to problems with high cognitive demand and greater topic complexity, but, for problems with greater search difficulty, the proportion of actions associated with preparing the answer is lower. In this sense, although the research suggests that students tend to copy and paste the answers directly from the internet (Dias & Bastos, 2014; Skaar, 2015), given the differences in the proportion of actions according to the types of difficulty of the problems, it is not evident that this is a specific behavior of the students, but it could instead depend on the characteristics of the problem, particularly the cognitive demand and complexity of the topic (Hinostroza et al., 2018).

On the other hand, in terms of the actions associated with monitoring the problem-solving process, although the proportion of actions is low, this is higher in the case of difficult problems (Greene et al., 2018), particularly those that address more complex topics. This could be explained by the requirement associated with understanding a subject with which the students are not familiar.

Finally, it is interesting to note that students perform a greater proportion of undesirable actions when solving easy problems, and particularly when dealing with simple topics. However, the trend is reversed when it comes to problems with a high search complexity, since in these cases the proportion of undesirable actions is greater. This may suggest that when students face search problems, they tend to replicate behaviors similar to those of non-experts (Sanchiz et al., 2017), but this behavior changes when the challenge is associated with the topic.

Conclusions

In short, the results show that easy problems require less effort and students obtain better results. In particular, in problems of low cognitive demand, students perform fewer actions associated with the formulation of the search and the preparation of the response. Also, in problems that deal with simpler topics, they devote less effort to preparing the answers, and for problems with lower search difficulty, they devote less effort to the formulation of the search.

Regardless of the type of difficulty in the simplest problems, students carry out a greater number of actions related to content appraisal. Similarly, for problems with low cognitive demand and search difficulty, the students conduct a larger number of actions associated with assessing the list of results than for the problems of greater difficulty.

Based on the results, we can conclude that student performance varies in a way that is inversely proportional to the difficulty of the problem and that the number of search actions is proportional to the difficulty. However, the distribution of actions at different stages is heterogeneous, since it depends on the difficulty of the problem and varies depending on the type of difficulty.

From the perspective of the research into solving information problems, on the one hand, these results imply that in order to understand the relationship between search actions and student performance, it is essential to analyze the pattern of search behavior considering every one of the stages and not simply the total actions carried out. On the other hand, the various types of difficulty of the problems are associated with different distributions of actions, to which is added the need to associate each type of difficulty with a specific pattern of behavior.

With respect to the implications of these results for the design of learning situations related to the characteristics of the information problems as they were categorized in this study, the fact that each type of problem difficulty is associated with a different search pattern allows the characteristics of information problems to be linked to certain learning objectives and/or development of specific digital skills. For example, if we want students to focus on analyzing the statement of the problem, it is likely that problems with greater search difficulty will generate more opportunities to discuss and analyze the formulation of the problem. On the other hand, problems of general intermediate difficulty could favor the analysis of the content of the websites found. However, difficult problems demand greater effort to assess the content and websites, which implies that it would be necessary to support students during these stages of the search process. In additionally, considering that students tend to perform more undesirable actions when solving easy problems, it may not be advantageous to use this type of problem in the context of school activities.

Although this study allowed a more profound examination of the effect produced by the characteristics of the problem difficulty type, such as cognitive demand, search difficulty, and complexity of the topics in the students' search process and performance, individual variables, such as the academic history the students and/or their ease of verbalization to follow the protocol of spoken thought, were not considered in this study. In additionally, the selection of the sample of students considered only those interested in taking part in the study, which entails limitations that restrict the generalization of the conclusions and open up new challenges to determine the effect of the individual variables.

The original paper was received on March 29th, 2019
The reviewed paper was received on August 5th, 2019
The paper was accepted on August 28th, 2019

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Annex A

Information problem

P1: Briefly define in your own words the method used to calculate the age to which people in various countries can live.

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 2; Difficulty: 4.

P2: Life expectancy in Chile has shown a sustained increase in the last 10 years. Describe at least three scientific reasons that influence the increase in life expectancy in Chile.

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 2; Difficulty: 4.

P3: Life expectancy has increased worldwide. Look at what is the difference in years between the country with the highest life expectancy and the country with the lowest life expectancy in South America. Identify the main reason for this difference and explain how it could be improved in the country with lower life expectancy.

Cognitive Demand: 2; Search Difficulty: 2; Topic Complexity: 2; Difficulty: 6.

P4: Name the five countries with the highest life expectancy in the world and explain the main consequences (at least three) that lead to progressive increase in life expectancy.

Cognitive Demand: 2; Search Difficulty: 1; Topic Complexity: 2; Difficulty: 5.

P5: Name the three highest-paid actresses in the last year.

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 1; Difficulty: 3.

P6: What is the plot of the most Oscar-nominated movie of the most Oscar-nominated director?

Cognitive Demand: 1; Search Difficulty: 2; Topic Complexity: 2; Difficulty: 5.

P7: Name the five movies released during 2015 that had the biggest percentage of financial earnings.

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 1; Difficulty: 3.

P8: Look for the equivalent to the Oscar award for actors that is of equal importance to musicians, theater actors, painters, writers, and scientists. Justify your answer.

Cognitive Demand: 2; Search Difficulty: 2; Topic Complexity: 1; Difficulty: 5.

P9: Name three art works by Claude Monet and the prices at which they are sold at present.

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 2; Difficulty: 4.

P10: What procedures are used to determine the value of new and old paintings?

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 2; Difficulty: 4.

P11: Compare the characteristics of the painting styles of Picasso, Goya, Rembrandt, and Salvador Dalí. Search for a painting by each artist that shows the same theme.

Cognitive Demand: 2; Search Difficulty: 2; Topic Complexity: 2; Difficulty: 6.

P12: If you had to organize an art fair with one painting for each famous artist, which ones would you present if you had to choose the most expensive painting for each style? Consider at least the Abstract, Pop, Realism, Surrealism and Impressionism styles.

Cognitive Demand: 2; Search Difficulty: 2; Topic Complexity: 2; Difficulty: 6.

P13: Name the active ingredients of the medication Mentix and the secondary effects of each of them.

Cognitive Demand: 1; Search Difficulty: 2; Topic Complexity: 1; Difficulty: 4.

P14: Mentix has what mechanisms of action on the central nervous system?

Cognitive Demand: 1; Search Difficulty: 1; Topic Complexity: 1; Difficulty: 3.

P15: Search for foods that are effective in keeping you awake and active (ignore beverages such as coffee, mate, tea, soft-drinks, and coca leaves). Choose three and compare the mechanisms that produce the desired effect.

Cognitive Demand: 2; Search Difficulty: 1; Topic Complexity: 1; Difficulty: 4.

Annex B

Difficulty of the problems

a) Cognitive demand

The level of cognitive complexity refers to different stages of difficulty in the questions, which aim to have the subject perform various types of cognitive actions to successfully answer the question.

- Low: Involves a level of receptive learning for the subjects who conduct the search. This implies that in order to solve the problem, the subjects are required to carry out activities such as understanding, remembering, and reproducing concepts, facts, procedures, and principles (Jansen et al., 2009; Rieh et al., 2016). Based on Bloom's revised taxonomy, this type of task involves basic cognitive levels, such as remembering and understanding.
- High: Involves a level of critical learning for the subjects who conduct the search. This implies that the subjects involve their own point of view in the review, analysis, and criticism of multiple sources from the internet to resolve the problem (Rieh et al., 2016). Based on the perspective of the cognitive levels of Bloom's revised taxonomy, this type of task involves higher cognitive levels of the taxonomy, such as applying, analyzing, and assessing (Krathwohl, 2002).

b) Difficulty of the search

The level of complexity of the search refers to the set of actions that subjects have to carry out to find the information required to solve the problem. This includes actions such as the number of steps to find the information, the availability of keywords in the sentence, whether it is possible to find the complete information in a single site, or, whether it is necessary to use multiple sources (Monchaux et al., 2015; Wildemuth et al., 2014).

- Low: In problems at this level there are coincidences between the terms of the statement and those in the results pages (Chevalier et al., 2015). This implies that it is possible to find the results, for example, by copying and pasting the sentence, or by selecting a couple of words from the sentence to search for. On the other hand, problems at this level require few iterations (steps and/or intersections) to find an answer (Wildemuth et al., 2014) and the same content is generally available on a large number of websites.
- High: In the problems at this level the formulation of the search is more complex because it is not possible to arrive at the answer with words used directly from the statement. In addition, more than one iteration is required to access the websites that contain the information, since in many cases, the subject must make intersections of information or parallel searches. Finally, it is necessary to collect information from more than one source to obtain a correct answer.

c) Complexity of the topic

As noted by Monchaux et al. (2015), the level of prior knowledge of the subject is one of the best predictors of performance in searching for information. Therefore, the level of complexity of the subject will be understood as the level of familiarity that subjects have with the topic of the problem.

- Low: Topics are considered to be at this level which are interesting to and familiar to young people between 18 and 20 years of age. In addition, it is considered that the information regarding these topics is easily accessible, for example, through social media, television, reference groups, or the internet
- High: Topics are considered to be at this level which, in a broad sense, are outside the general knowledge of young people between 18 and 20 years old. This level involves issues that are not commonly considered by young people.