Universitat de Lleida

Information-problem solving in Secondary Education: analyses of cognitive processes using Web information and their improvement through embedded instruction

Esther Argelagós

Information-problem solving in Secondary Education: analyses of cognitive processes using Web information and their improvement through embedded instruction

Esther Argelagós

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En memòria
de *ma jaya*, Maria,
i *mon jayo*, J. Josep

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Preface

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Summary-Resumen-Resum

Nowadays, the Internet has become one of the most important information sources in both personal and academic life. However, the complex cognitive activities involved in the processes of gathering and processing information from the Web (*Information-problem solving*, IPS) are not instinctively acquired. The main objectives of this dissertation consist, on the one hand, in identifying and describing the challenges that secondary students should overcome to solve information-problems more efficiently, and, on the other hand, in studying the effect of an embedded instruction on the students' cognitive processes involved in IPS. This research also aims to draw educational implications for the teachers to help secondary students to enhance their digital competences while learning curricular contents.

To accomplish these general objectives, four different research studies have been carried out. The first study compares and analyses three different techniques which assess IPS cognitive processes. The second study describes in detail the challenges that secondary students face with an IPS task. The need of instruction on IPS cognitive processes led us to analyse the impact on an instructional process embedded in the academic curriculum in order to help students in their difficulties (third study). The fourth study provides conclusions based on a more qualitative and in-depth analysis on the kind of processes developed by students regarding the IPS instruction received.

The main conclusions extracted from this research dissertation are the following: (a) Different techniques can give a valuable contribution to the understanding of the IPS cognitive processes and their election will depend on the objectives and the design of the research. (b) The sole access and exposure to Internet does not warrant to students a successful IPS process, but they need to become digitally literate. (c) Since School has the mission of enabling students to become active citizens, an adequate IPS instruction at school is needed in order to help students to develop their digital competences. (d) The embedded, structured and supported IPS instruction designed by the COnTIC group (UdL) has been effective in students of Secondary Educational classrooms to improve critical IPS cognitive processes. (e) Scaffolds that support IPS instruction should be carefully designed; human and technological scaffolds should be appropriately orchestrated, in order to fully take advantage of their affordances.

Hoy en día, Internet se ha convertido en una de las más importantes fuentes de información en la vida personal y académica de los individuos. Sin embargo, las actividades cognitivas complejas involucradas en los procesos de acceso y manejo de la información de la Web (*Information-problem solving*, IPS) no se adquieren de una manera espontánea. Los principales objetivos de esta tesis consisten, por un lado, en identificar y describir los problemas que los estudiantes de secundaria deberían superar para resolver problemas basados en información Web de manera más eficiente y, por otro lado, en estudiar el efecto en los procesos cognitivos de los estudiantes de una instrucción IPS integrada en el curriculum escolar. Esta investigación también pretende aportar implicaciones educacionales para la práctica docente para ayudar a estudiantes de secundaria a mejorar sus competencias digitales al aprender contenidos curriculares en sus clases cotidianas.

Para alcanzar estos objetivos generales, se han realizado cuatro estudios de investigación diferentes. El primer estudio compara y analiza tres técnicas distintas que evalúan procesos cognitivos implicados en IPS. El segundo estudio describe detalladamente los retos que enfrentan los estudiantes de secundaria en una tarea IPS. La necesidad de la instrucción sobre procesos cognitivos IPS nos lleva a analizar el impacto de un proceso de instrucción integrada en el currículum académico a fin de ayudar a los estudiantes en sus dificultades al resolver un problema mediante información digital (tercer estudio). El cuarto estudio aporta conclusiones basadas en un análisis más cualitativo y profundo sobre los tipos de procesos desarrollados por los estudiantes en relación con la instrucción IPS recibida.

Las principales conclusiones que se extraen esta tesis de investigación son las siguientes: (a) Existen diferentes técnicas de recogida de datos que pueden dar una valiosa contribución a la comprensión de los procesos cognitivos IPS y su elección dependerá de los objetivos y el diseño de la investigación concreta. (b) El simple acceso y exposición a Internet no garantiza que los alumnos accedan y manejen adecuadamente la información digital presente en Internet, sino que necesitan ser alfabetizados digitalmente. (c) Ya que la Escuela tiene la misión de capacitar a los estudiantes para que lleguen a ser ciudadanos activos y críticos, es necesaria una adecuada instrucción IPS en las instituciones educativas para ayudar a los estudiantes a desarrollar sus competencias digitales. (d) La instrucción IPS integrada, estructurada y apoyada, diseñada por el grupo COnTIC (UdL) se ha mostrado eficaz en la mejora de los procesos cognitivos clave implicados IPS en los estudiantes de educación secundaria. (e) El conjunto de andamios que apoya el proceso de instrucción IPS debe diseñarse y coordinarse cuidadosamente: el andamiaje humano y tecnológico deben ser adecuadamente orquestado, para obtener así el máximo provecho de sus potencialidades.

Avui dia, Internet s'ha convertit en una de les més importants fonts d'informació en la vida personal i acadèmica dels individus. No obstant això, les activitats cognitives complexes involucrades en els processos d'accés i maneig de la informació de la Web (*Information-problem solving*, IPS) no s'adquireixen d'una manera espontània. Els principals objectius d'aquesta tesi consisteixen, d'una banda, a identificar i descriure els reptes que els estudiants de secundària haurien de superar per resoldre problemes basats en informació Web de manera més eficient i, d'altra banda, a estudiar l'efecte en els processos cognitius dels estudiants d'una instrucció IPS integrada en el curriculum escolar. Aquesta investigació també pretén aportar implicacions educacionals per a la pràctica docent per ajudar a estudiants de secundària a millorar les seves competències digitals en aprendre continguts curriculars en les seves classes quotidianes.

Per aconseguir aquests objectius generals, s'han dut a terme quatre estudis d'investigació diferents. El primer estudi compara i analitza tres tècniques diverses que avalúen processos cognitius implicats en IPS. El segon estudi descriu detalladament els reptes que enfronten els estudiants de secundària en una tasca IPS. La necessitat de la instrucció sobre processos cognitius IPS ens porta a analitzar l'impacte d'un procés d'instrucció integrada en el currículum acadèmic a fi d'ajudar als estudiants en les seves dificultats en resoldre un problema mitjançant informació digital (tercer estudi). El quart estudi aporta conclusions basades en una anàlisi més qualitativa i profunda sobre els tipus de processos desenvolupats pels estudiants en relació amb la instrucció IPS rebuda.

Les principals conclusions que s'extreuen aquesta tesi d'investigació són les següents: (a) Existeixen diferents tècniques de recollida de dades que poden donar una valuosa contribució a la comprensió dels processos cognitius IPS i la seva elecció dependrà dels objectius i el disseny de la investigació concreta. (b) El simple accés i exposició a Internet no garanteix que els alumnes accedeixin i manegin adequadament la informació digital present en Internet, sinó que necessiten ser alfabetitzats digitalment. (c) Ja que l'Escola té la missió de capacitar als estudiants perquè arribin a ser ciutadans actius i crítics, és necessària una adequada instrucció IPS en les institucions educatives per ajudar als estudiants a desenvolupar les seves competències digitals. (d) La instrucció IPS integrada, estructurada i recolzada, dissenyada pel grup COnTIC (UdL) s'ha mostrat eficaç en la millora dels processos cognitius clau implicats IPS en els estudiants d'educació secundària. (i) El conjunt de bastides que recolza el procés d'instrucció IPS ha de dissenyar-se i coordinar-se acuradament: les bastides humanes i tecnològiques han de ser adequadament orquestrades, per obtenir així el màxim profit de les seves potencialitats.

Chapter 1. Introduction

The research dissertation presented in the following pages has the main purpose of diving into the world of the problem-solving processes with the use of information from the Internet. More specifically, the main objectives of this dissertation are, on the one hand, to identify and describe the main challenges that students might overcome in dealing with Web information to solve a task or a problem and, on the other hand, to study how to help students to become more efficient in such a process and in order not to sink in the Internet ocean.

This introductory chapter has a double finality. The first finality is to present some features and experiences that gave form to the general idea of this dissertation and contextualized the initial interest, origin and development of its content –problem-solving with the use of the Internet at school. The second finality of this chapter is to present the general structure that this dissertation follows, shortly advancing the content of each chapter in order to make their reading and understanding easier.

Since I was a child, I have always liked to balance the possible options with their pros and cons in order to make a good decision. Later, I realized that the process to make a decision has a lot of points in common with the process to solve a problem, since decision-making is also a kind of problem (Jonassen, 2007). However, my interest in the study of the problem-solving process started during my degree in Teacher Education, particularly in the speciality of Special Education. Psychology was one of my passions and, during my degree, the optional subjects I usually took were those which involved educational psychology issues. I would think that, even when I never worked as a teacher or educator, everything I was learning could be applied in my everyday life. The problem-solving process was one of these things.

After my degree, I moved to Teruel, since I was called to work as a substitute teacher in Primary and Secondary Public Schools for two years. The second year of that period I was involved in a rural school in Ariño[1] (Teruel), whose educators were aware of the importance of technology integration in Education. They also were sensitive to the meaning of authentic activities for significant learning (for instance, collaborative projects involving parents, community, external experts, etc.). During that time, I continued my studies in Psycho-Pedagogy in the *Universitat de Lleida*. My interest in Educational Psychology, and teaching-learning practices was increasing, joining both the practice at school and the theoretical issues from the University.

In that context and moment, the Catholic Community I belong to –*Comunidad Jerusalén*[2]–, was aware that certain parts of the world needed specific help, particularly Mozambique. It was an important decision in my life to be available to fly to that unknown country and to work there in whatever field that was needed. It might mean to pause (or even stop) my professional career; however, I flew. In the beginning, my work was going to consist in something that had nothing to do with Education; however, the first week that I stayed there, the director of the *Faculadade de Educação e Comunicacão* of the *Universidade Católica de Moçambique*[3] *(UCM)* called me to teach subjects on Educational Psychology, Social Psychology, Developmental Psychology, etc.

I worked in that faculty for five years. The UCM created important engagements with the Maastricht University[4] (UM) from the Netherlands, in order to integrate the Problem-based Learning method (PBL) in its faculties. As a coordinator of the Educational Department of our faculty in UCM and with the UM support, I had to guide the collaborative work to develop a new curriculum based on the PBL method, which was extremely hard, but also highly exciting and satisfying. Both teachers and students had to change their minds about teaching and learning, since we had been used to traditional teaching until then. Nevertheless, it was a great experience and opportunity to learn about learning, teaching, and problem solving.

Coming back to Spain, my contacts with the *Universitat de Lleida* continued. A meeting with Dr. Manoli Pifarré and an interesting exchange of experiences and ideas

[1] http://adigital.pntic.mec.es/~arino

[2] http://cjerusalen.org

[3] http://www.ucm.ac.mz

[4] http://www.maastrichtuniversity.nl

about problem-solving processes and the use of technologies at school started a set of collaborative pieces of work in the research group *COnTIC*[5] *(Cognició, Context & les Tecnologies de la Informació i la Comunicació)*. This time, the context of problem-solving processes were the Spanish Secondary Education and the technology learning environments, and the main purpose was to help students to deal with the Internet as a useful tool to learn at school.

This miscellaneous set of experiences constituted the starting point of this dissertation. Since that moment, the interest and leaning experience in this field was *in crescendo*, and the support from the COnTIC group, in particular from Dr. Manoli Pifarré, was always present and efficient. My collaboration in new projects and diverse research activities within the COnTIC group also contributed to construct a wider view of the field of learning with technologies. A pre-doctoral scholarship awarded by the *Generalitat de Catalunya*[6] to carry out the PhD dissertation as well as to collaborate with the COnTIC group, was undoubtedly a great help in being totally immersed in the research group and activities, and also to take advantage, for instance, the possibility to take a master’s degree, to do a research stage, to participate in conferences and congresses, etc.

In this context, I took the *Máster Interuniversitario en Psicologia de la Educación*[7] *(MIPE)*, which is led by Dr. César Coll, from the *Universitat de Barcelona* and of which all the public universities of Catalonia take part. Theoretical, methodological, and a research basis were provided in that master’s degree in order to develop our own research projects.

Furthermore, another point that also supported the development of the research presented in this dissertation was the pre-doctoral stage carried out at the Department of Learning and Cognition of the CELSTEC[8] (Centre for Learning Sciences and Technologies) in the Netherlands. During this research stage, I had the opportunity to

[5] COnTIC (http://contic.udl.cat) is a consolidated research group recognized by the *Generalitat de Catalunya*, and led by Dr. Manoli Pifarré. More information about the research line about digital literacy can be found in the Introduction of Chapter 4 of this dissertation: “Research design”.

[6] Agència de Gestió d'Ajuts Universitaris i de Recerca (http://www10.gencat.net/agaur).

[7] http://www.psyed.edu.es/mipe

[8] http://celstec.org

delve into the investigation conducted by expert researchers in information-problem solving. Particularly, it was an unequal chance to qualify and improve the coding scheme developed to analyse the data. In addition, I was allowed to learn new ways of research, new techniques and apparatus, and to conduct a piece of research therein, with the support and collaboration of CELSTEC researchers and materials. It also was a good starting point for new contacts between COnTIC and CELSEC in order to conduct further joint research studies.

Within this framework, the dissertation that we[9] have presented in this report has the following main purposes. On the one hand, one important objective is to **identify and describe in detail the main challenges that secondary students should overcome to solve** information-problems more efficiently. On the other hand, another critical purpose is to **study the effect of an embedded instruction** on the students' cognitive processes involved in problem solving with the use of the Internet. In addition, this research aims to draw **conclusions and educational implications** for teachers –specifically, for the main educational agents: classroom teachers– in order to provide guidelines to help secondary students and enhance their digital competences while learning curricular contents at school.

The *e*Learning Action Plan (European Commission, 2000) about the use of technologies and Internet to improve the quality of student learning has been one of the main challenges of European Education. Students should develop a set of specific digital skills and procedures to better exploit the potential of the information and communication technologies and the Internet as learning tools. However, the development of these strategies in students does not occur spontaneously through the simple interaction of student and technologies (Wood, 2009). Educational research points out that students present difficulties in searching and tackling the Internet information to learn (Guinee, Eagleton, & Hall, 2003; Pejtersen & Fidel, 1999; Pifarré & Gòdia, 2006). Therefore, there is a need to study how to incorporate the Internet for learning specific curricular contents and boosting the development of the skills required for the use of the Internet's potential.

[9] From now on, in this dissertation I will use "the royal we". I chose this form of expression because it better reflects the collaborative environment in which research dissertation has been developed.

In this context, the dissertation that we start with these introduction pages, pursues to communicate in a systematic way the theoretical background of the content investigated in this work, the research design followed to investigate it, the results obtained and developed in the last years, and the theoretical discussions on the contributions and limitations provided by those results, as well as the lines open to continue, in the future, our research. We present this dissertation with a structure composed by 9 chapters, including this introduction chapter.

Chapter 2 presents theoretical contributions on the problem-solving process, which will serve as a basis to study the concept of problem solving using the digital information available in the Internet. Researchers point out the necessity of considering the variables of factors that have an influence on the problem-solving process. They also highlight that the process is composed by several, important phases or steps to successfully solve a problem. In addition, regulation is another critical element on the problem-solving process. Considering these elements, we will introduce and describe the concept of information-problem solving (that is, the process of problem-solving with the use of the Internet as a main source), we will identify its influence variables, and we will explain a model to understand and analyse the information-problem solving process. Before concluding this chapter, we will present the difficulties of students in information-problem solving.

In Chapter 3, first we will present and analyse a set of teaching and learning methods that involve problem-solving processes. Second, we will analyse research studies on IPS instruction carried out to improve information-problem solving cognitive processes on students, especially in Secondary Education. Third, we will describe the methodological and instructional proposal assessed in our study, based on the analyses of the previous sections of the chapter and carried out by the COnTIC research group.

On the basis of the previous chapters and in the research line on digital literacy of COnTIC group, Chapter 4 is devoted to the design of the research conducted and analysed in this dissertation. Particularly, in this chapter we will present the main objectives that guide the empirical part of this dissertation. To accomplish the general objectives, methodological and empirical options have been taken. Methodological issues will be raised in this chapter, as regards the kind of methods used in this dissertation. Empirical options about how the pieces of research of this dissertation have been conducted will be introduced. Particularly, the four studies carried out in this research work to accomplish the general objectives also will be introduced in this chapter.

The following four chapters (5 to 8) report those four different studies that aim to present each piece of research conducted. Therefore, each chapter reports one study and includes the following sections: theoretical introduction, method, results, and discussion. In this way, Chapter 5 presents Study 1, in which three different techniques that assess information-problem solving cognitive processes will be analysed and compared. Departing from the conclusions of this study, Chapter 6 presents Study 2, which has the purpose of describing in detail the challenges or difficulties that secondary students face while solving information problems in their classrooms to learn curricular contents. The need of instruction on information-problem solving cognitive processes lead us to analyse the impact of a kind of instruction embedded in the academic curriculum in order to help students in their difficulties (Chapter 7, Study 3). The fourth and last study, presented in Chapter 8, has the objective of complementing the findings obtained in the third study, in a more qualitative and in-depth way.

Although the four studies (presented from Chapters 5 to 8) include a section to discuss the results obtained, a general discussion will be presented in Chapter 9, to conclude our exposition. To do that, first we will relate the results and conclusions retrieved by each study with the objectives that guided the entire research (and presented in Chapter 4 –Research design). Second, we will complete the general discussion by adding educational implications for the teachers, in order to provide guidelines to help Secondary Students to enhance their information-problem solving processes while learning curricular contents at school. Third, we will summarize the main conclusions of our work and, finally, we will present our main contributions, limitations, and open lines of further research in the field of teaching and learning with the use of technologies and problem-solving strategies.

Capítulo 2. El proceso de resolución de problemas

El objetivo principal de esta disertación consiste, por un lado, en analizar las dificultades a las que se enfrentan los estudiantes de Educación Secundaria al llevar a cabo un proceso de resolución de problemas mediante la información digital encontrada en Internet y, por otro lado, en analizar la incidencia de un proceso de instrucción seguido por estudiantes de Secundaria encaminado a desarrollar las habilidades necesarias para resolver problemas basados en la Web y al mismo tiempo aprender contenidos curriculares en sus clases habituales.

En el presente capítulo, estudiaremos las aportaciones teóricas realizadas sobre el proceso de resolución de problemas, lo cual nos servirá de base para poder estudiar dicho proceso utilizando la información digital presente en Internet. Los diversos estudiosos coinciden en apuntar la necesidad de tener en cuenta los factores que influyen en el proceso de resolución de problemas, así como sus fases principales y la importancia de los aspectos reguladores durante todo el proceso.

Sobre esta base, añadiremos además un nuevo elemento que matiza el proceso de resolución de problemas en nuestros días: la *World Wide Web* (WWW) como principal fuente de información, cuyas características nos aportan la especificidad del proceso IPS (*Information Problem Solving*, o proceso de resolución de problemas mediante información digital).

Ya en el marco de los procesos IPS, analizaremos los factores o variables que lo influyen, así como en las fases o habilidades y en las actividades reguladoras que le dan sentido. Mediante el modelo IPS propuesto por Brand-Gruwel, Wopereis y Vermetten (2005) describiremos dichas fases y aspectos reguladores que forman parte del proceso de resolución de problemas cuando se utiliza Internet como fuente de información.

Antes de cerrar el capítulo, describiremos diversas dificultades que la mayoría de los aprendices encuentran en cada una de las fases o habilidades, así como en las actividades de regulación, lo cual nos servirá como punto de partida para nuestro posterior análisis sobre las dificultades a las que se enfrentan los alumnos de secundaria. En posteriores capítulos retomaremos dichas dificultades, al llevar a cabo un estudio de ámbito local sobre las mismas.

A lo largo de los diferentes capítulos de esta disertación, tendremos asimismo presente el modelo IPS presentado en este capítulo, que nos servirá como referente, tanto para describir el proceso instruccional aplicado en escuelas de secundaria, como para explicar el desarrollo de un sistema de categorías con el que analizar la incidencia de dicho proceso de instrucción escolar en las habilidades IPS de los estudiantes que participaron en el mismo.

1. El proceso de resolución de problemas

1.1. Aportaciones teóricas al proceso de resolución de problemas

El proceso de resolución de problemas ha sido un objetivo muy importante en la educación. Al mismo tiempo, los investigadores y teóricos han ido avanzando notablemente diferentes concepciones y métodos de estudio. Numerosas fases de solución de problemas y actividades de aprendizaje asociadas se han propuesto desde diferentes aproximaciones teóricas como el procesamiento de la información (p.e., Brandsford & Stein, 1984; Chase & Simon, 1973), la perspectiva cognitiva (p.e., Chi, Feltovich & Glaser, 1981; van Merriënboer, Clark & de Croock, 2002) y el constructivismo (p.e., Mayer & Wittrock, 2006). A continuación, revisamos diversos enfoques que analizan el proceso de resolución de problemas, a fin de tener una idea general, que no exhaustiva, acerca de la resolución de problemas.

Polya (1957), un matemático húngaro, analizó procesos de resolución de problemas codificando conversaciones entre profesores y alumnos durante clases de matemáticas. Sus conclusiones establecieron la base para el pensamiento actual en la enseñanza de las matemáticas y la resolución de problemas. El modelo de Polya para la resolución de problemas consta de cuatro pasos que utilizan las 3 Rs de solución de problemas: *Request-Response-Result,* y una verificación del resultado. Los cuatro pasos son los siguientes: (1) comprensión del problema (reconocer qué se requiere para solucionarlo), (2) la elaboración de un plan (responder a lo que se pide), (3) realizar el plan (desarrollar el resultado de la respuesta) y (4) evaluar (valorar qué dice el resultado). Estas actividades, a menudo combinadas con la heurística (por ejemplo, analogía, generalización, inducción, especialización, etc.), describen el proceso lineal que Polya detectó durante el proceso de resolución de problemas de los estudiantes.

Basándose en el enfoque de Polya, Bransford y Stein (1984) desarrollaron un modelo de resolución de problemas de cinco etapas consistente en identificar problemas y oportunidades, definir objetivos, explorar posibles estrategias, anticiparse a los resultados y actuar, y finalmente evaluar el proceso y el aprendizaje. Estos autores encontraron que los individuos llegan a ser eficaces y creativos en la resolución de problemas cuando consiguen analizar sus propias estrategias y son capaces de usar métodos alternativos para los problemas a los que se enfrentan. Las etapas formuladas por Bransford y Stein han supuesto también una base para los actuales modelos de solución de los problemas.

Un clásico estudio llevado a cabo por de Groot (1966) halló que la superioridad de los expertos de ajedrez sobre los novatos se debía principalmente a las diferencias en las construcciones importantes de las relaciones entre las piezas de ajedrez en el tablero. En otras palabras, los expertos eran más capaces que los novatos de reconfigurar las posiciones de las piezas en el tablero de ajedrez. Las conclusiones de este estudio demostraron, pues, que la ventaja de los expertos para resolver la tarea no era debida ni a un mayor trabajo de memoria ni solamente a la posición individual de las piezas, sino sobre todo a la capacidad de los expertos para reconocer esquemas significativos y relaciones entre las diferentes piezas de ajedrez. Cuando un individuo no es capaz de organizar las piezas de una manera significativa, sólo recuerda la posición de un número de piezas, como suelen hacer las personas poco expertas.

Ampliando los resultados obtenidos por de Groot (1966), Chase y Simon (1973) encontraron que las personas expertas son capaces de recordar más configuraciones de patrones que las principiantes, combinando y recuperando trozos de dichos patrones. Hisnley, Hayes y Simon (1977) perfilaron conclusiones similares, destacando la importancia de la organización de los conocimientos previos en la resolución de problemas matemáticos.

La importancia de esquemas previos en el proceso de resolución de problemas llevó a Gick (1986) a distinguir dos formas de resolver un problema, teniendo en cuenta la existencia o no de esquemas anteriores acerca del problema. Según los resultados de las investigaciones llevadas a cabo por esta autora, cuando se activa un esquema previo, el proceso de resolución del problema se da de la siguiente manera: (1) construcción de representación, (2) ejecución de un procedimiento, y (3) resolución del problema propiamente dicha. Cuando no está activado el esquema previo, el proceso de resolución del problema necesita una fase adicional en el proceso de búsqueda y el camino se realiza como sigue: (1) construcción de la representación, (2) búsqueda de la solución del problema, (3) ejecución de un procedimiento, y (4) resolución del problema.

Más recientemente, el modelo Big6™ de Eisenberg y Berkowitz (1990) distingue seis etapas a fin de fomentar las habilidades de resolución de problemas: (1) definición del problema, (2) estrategias de búsqueda de la información, (3) localización y acceso a las fuentes de información, (4) uso de la información, (5) síntesis, y (6) evaluación. En esta propuesta se basa el modelo IPS que tomaremos como referencia a lo largo de todo este estudio de investigación.

Desde una perspectiva más cognitiva, Chi, Feltovich y Glaser (1981) compararon el proceso de categorización de problemas de física entre personas expertas y principiantes. A los participantes se les pidió que clasificaran un conjunto de problemas de física de acuerdo a la similitud de los procedimientos para resolverlos. Las personas principiantes clasificaron los problemas teniendo en cuenta aspectos superficiales y creando esquemas más sencillos relacionados con el conocimiento declarativo. Por el contrario, las personas expertas clasificaron los problemas considerando los principios abstractos de física involucrados en los problemas y mediante la creación de esquemas más complejos relacionados con conocimiento declarativo y procedimental. Las personas novatas se enfocaron en la creación de esquemas concretos y pobres, no esenciales y difícilmente aplicables a otros contextos, mientras que los expertos se centraron en la creación de esquemas basados en los principios de la física básica y en aspectos generales aplicables a otras situaciones. Los estudios de estos autores indican que los conocimientos declarativos acumulados mediante la práctica ayudaron a las personas expertas a internalizar el proceso de resolución de problemas y a ser capaces de omitir algunos procedimientos concretos e innecesarios durante el proceso de dicha resolución.

Al examinar la relación entre la carga cognitiva y los enfoques educativos, van Merriënboer, Clark y de Croock (2002) identificaron demandas cognitivas esenciales para el aprendizaje complejo, el cual siempre involucra, según dichos autores, la consecución de múltiples objetivos. Su enfoque destaca varias metas y objetivos orientados a la actividad y establece un paralelismo con otros muchos modelos de resolución de problemas. Este enfoque se centra en coordinar cuatro componentes interrelacionados: (1) las tareas de aprendizaje y los contextos de resolución de problemas deberían incluir experiencias concretas, auténticas, y *whole-task*, (2) la información de apoyo y evidencia para la solución del problema deberían tender un puente en la brecha entre el conocimiento previo de los alumnos y las tareas de resolución de problemas, (3) la información *justo-a-tiempo* debería guiar a los alumnos de manera procedimental hacia las actividades concretas de resolución de problemas, y (4) la práctica de la *part-task* debería permitir a los estudiantes ejercitar prácticas de automatización en las habilidades complejas adquiridas en la resolución de problemas.

Desde un enfoque constructivista, Mayer y Wittrock (2006) caracterizaron cuatro funcionalidades esenciales de solución de problemas: (1) cognitiva, (2) centrada en el proceso, (3) dirigida, y (4) personal. Esta propuesta enfatiza la exploración de la solución de múltiples rutas durante la solución de problemas y se centra en los procesos cognitivos individuales. Estos autores definieron el proceso de resolución de problemas como procesamiento cognitivo dirigido a transformar una situación dada en una situación diana cuando no se dispone de ningún método obvio de solución. Sostuvieron que el proceso de resolución de problemas requiere que los estudiantes representen internamente problemas manifestados externamente a través de las actividades cognitivas de planificación, monitorización, ejecución y autorregulación.

Siguiendo la línea de la propuesta de Mayer y Wittrock, Jonassen (2007) identificó problemas poco estructurados para cuya respuesta no existe un solo método, debido a que hay una gran cantidad de tipos de problemas, como los siguientes: problemas de historia, problemas inductivos, problemas basados en la toma de decisiones, problemas sobre política, problemas de diseño, y problemas-dilema. Ampliando la categorización de factores que influyen en la resolución de problemas propuesta por Smith (1961), Jonassen (2007) estableció dimensiones que incluían factores internos –características individuales de las personas que resolvían los problemas, como: experiencia, conocimiento declarativo, habilidades de razonamiento y creencias epistemológicas–, factores externos –sobre cómo los problemas se forman y se representan, como: complejidad, estructura y dinamismo–, y factores situacionales –por ejemplo, las expectativas culturales y características de contexto.

Más recientemente, otra definición de resolución de problemas es la que aportan Kim y Hannafin (2010). Estos autores definen el proceso de resolución de problemas como situado, deliberado, dirigido por el individuo, y orientado a la actividad de buscar soluciones divergentes a problemas auténticos a través de múltiples interacciones entre el individuo, las herramientas disponibles y otros recursos. Estos autores destacan cinco actividades de resolución de problemas: (1) identificación del problema y compromiso para resolverlo, (2) exploración de las evidencias, (3) reconstrucción de la explicación, (4) comunicación y justificación de la explicación, y (5) revisión y reflexión de explicación.

* * *

Como se puede apreciar, el proceso que hay que llevar a cabo para resolver un problema ha sido ampliamente estudiado desde diferentes enfoques y a lo largo de diferentes épocas. Diversos autores, desde distintas perspectivas teóricas, coinciden en señalar algunos puntos principales en el proceso de resolución de problemas, además de aportar cada uno su contribución específica a la construcción de la teoría sobre cómo las personas resuelven problemas. La figura 1 pretende esquematizar las aportaciones teóricas descritas en este apartado y a la vez identificar puntos convergentes entre ellas, lo cual nos da indicadores para inferir los puntos más importantes en el proceso de resolución de problemas.

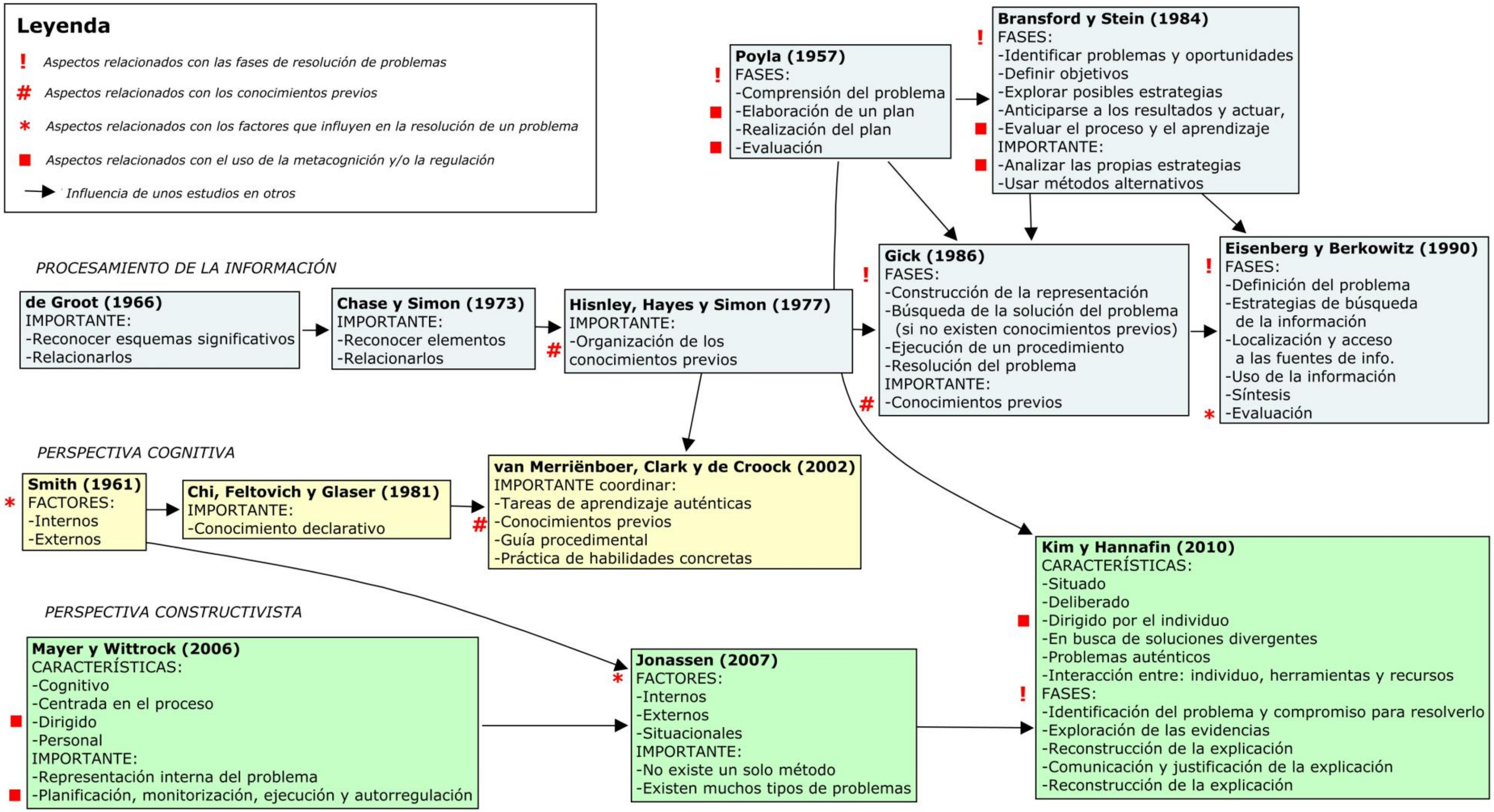

Figura 1. Aportaciones teóricas sobre el proceso de resolución de problemas

En la figura anterior subrayamos tres puntos principales en los que los autores convergen: (1) existen factores que influyen en la resolución de problemas, entre los cuales destacamos la importancia de los conocimientos previos, (2) existen unas las fases clave necesarias para un adecuado proceso de resolución de un problema, y (3) resulta importante el uso de la metacognición y la regulación durante dicha resolución. En los párrafos siguientes nos centramos en cada uno de estos aspectos.

En primer lugar, uno de los puntos en el que los diferentes autores coinciden, se refiere a los **conocimientos previos** del individuo, que necesitan ser activados (Gick, 1986), organizados (Hisnley et al., 1977) y relacionados con otros elementos de los que se compone el problema (Chase & Simon, 1973; de Groot, 1966; van Merriënboer et al., 2002). Sin la activación de los conocimientos previos será difícil saber qué información ser requiere para dar solución al problema y habrá dificultades para integrar la nueva información con los esquemas ya existentes, aspecto necesario para que el aprendizaje –y, por tanto, la resolución del problema– tenga lugar.

Podemos entender el conjunto de conocimientos previos del individuo como parte de los factores –en este caso, internos– que influyen en la resolución de problemas. A este respecto, numerosos estudios convergen en la necesidad de tener en cuenta los diversos **factores** que influyen en la resolución de un problema, así como sus dimensiones y matices. Considerar solamente los factores internos del individuo, como los conocimientos previos que describíamos en el párrafo anterior, o sus habilidades cognitivas, experiencia, conocimiento declarativo o procedimental, creencias epistemológicas, etc., sería dejar de lado otras variables externas al individuo y relacionadas con su contexto (Smith, 1961; Jonassen, 2007).

En cuanto al segundo punto, existe una coincidencia –aun con los diferentes matices aportados por los diversos autores– en señalar que el proceso de resolución de problemas está formado por varias **fases** (Bransford & Stein, 1984; Eisenberg & Berkowitz, 1990; Gick, 1986; Kim & Hannafin, 2010; Poyla, 1957): una **fase inicial** en la cual el problema es identificado, analizado, representado y/o comprendido, y en la que se elabora un plan para resolverlo; una **fase intermedia** en la que se acaba de concretar el plan y se lleva a cabo, poniendo en marcha estrategias cuando falta información necesaria para resolver el problema, y en la que se resuelve de una manera efectiva el mismo; y finalmente una **fase final** en la cual se da una solución definitiva al problema y se evalúa dicha solución.

El último punto, aunque no por ello sea el menos importante, está relacionado con el uso de la **metacognición** durante el proceso de resolución de problemas. La metacognición se refiere al conocimiento que uno tiene sobre sus propios procesos cognitivos (Brown, 1987; Flavell, 1976) así como a la regulación de la cognición y la conducta en base a los propios aspectos cognitivos, concretada en procesos como planificación, monitorización, y revisión (Brown, 1987). A este respecto, las aportaciones teóricas analizadas al inicio de este capítulo mostraban coincidencia en apuntar como elementos importantes dentro del proceso de resolución de problemas, los siguientes: analizar las propias estrategias (Bransford & Stein, 1984), planificar (Poyla, 1957; Mayer & Wittrock, 2006), monitorizar, autorregular (Mayer & Wittrock, 2006) y evaluar (Poyla, 1957; Bransford & Stein, 1984; Eisenberg & Berkowitz, 1990; Mayer & Wittrock, 2006).

Estudiosos de la metacognición también coinciden en relacionarla con la calidad en la resolución de problemas (Duell, 1986; Stenberg, 1986). En concreto, muchos estudios han revelado que la calidad de la regulación está directamente relacionada con la efectividad y la eficiencia en el proceso de resolución de problemas (Flavell, 1976; Stenberg, 1986). Debido a dicha importancia, antes de continuar, dedicaremos un pequeño espacio en este apartado para relacionar la metacognición y la regulación con la resolución de problemas, y clarificar dichos términos.

1.2. La metacognición y la regulación en el proceso de resolución de problemas

En la década de los setenta, J. H. Flavell acuñó el término "metacognición", definiéndolo con estas palabras: "*Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning-relevant properties of information or data. For example, I am engaging in metacognition (...) if I notice that I am having more trouble learning A than B; if it* *strikes me that I should double check C before accepting it as fact.”* (Flavell, 1976: 232).

En otras palabras, la metacognición puede definirse como “*that segment of your (a child’s, an adult’s) stored world knowledge that has to do with people as cognitive creatures and with their diverse cognitive tasks, goals, actions and experiences.*” (Flavell, 1979: 906). Por ejemplo, si una persona cree que aprende mejor cuando recuerda una información con sus propias palabras que al pie de la letra, está haciendo uso de la metacognición.

Flavell defendió que la metacognición explica por qué niños de diferentes edades se ocupan de tareas de aprendizaje de diferentes maneras, es decir, desarrollan nuevas estrategias de pensamiento. Estudios posteriores confirman esta conclusión (Duell, 1986), así como el hecho de que con la edad demuestran más conciencia en sus procesos de pensamiento.

Por su parte, Ann Brown, que ya en 1975 había escrito un trabajo sobre “*Knowing, knowing about knowing, knowing how to know*”, también distinguió dos tipos de metacognición: (a) conocimiento sobre la cognición (aquello que se conoce sobre los propios procesos cognitivos) y (b) regulación de la cognición, dando a este último bastante énfasis y considerando su potencialidad reguladora de la cognición (Brown, 1987).

Ann Brown define la regulación como el hecho de conocer la utilidad de diferentes estrategias de intervención. En otras palabras, la persona que se auto-regula es la persona que es capaz de cambiar su comportamiento cuando hace una auto-valoración del desempeño no óptimo de una tarea. Además, Brown (1987) identificó cuatro aspectos dentro del componente regulativo de la metacognición: planificación, monitorización, evaluación, y revisión. (1) En primer lugar, la **planificación** se refiere a la deliberación de las actividades que organizan todo el proceso de aprendizaje. Estas acciones de planificación consisten en el establecimiento del objetivo de aprendizaje, la secuencia de aprendizaje, las estrategias de aprendizaje y el tiempo de aprendizaje esperado. (2) En segundo lugar, la **monitorización** consta de las actividades que moderan el proceso de aprendizaje que está teniendo lugar. Por ejemplo, los aprendices pueden preguntarse a sí mismos cuestiones como “¿qué estoy haciendo?”, “¿estoy yendo por el camino correcto?”, “¿cómo puedo hacerlo?”, “¿qué información es importante para completar las tareas dadas?", "¿podría hacerlo de otra manera?", "¿debería ajustar mi ritmo dependiendo de la dificultad?", etc. (Lee & Baylor, 2006). Estas actividades de monitorización se suelen llevar a cabo durante las actividades de aprendizaje. (3) En tercer lugar, **evaluar** el propio proceso de aprendizaje implica una valoración del progreso actual de la actividad. (4) Por último, la **revisión** del propio proceso de aprendizaje consiste en modificar los planes previos respecto a los objetivos, estrategias y otros aspectos de aprendizaje.

Así como Flavell dio más énfasis al conocimiento metacognitivo, y Brown enfatizó más las habilidades metacognitivas o regulación (Lee & Baylor, 2006), también otros autores han ido elaborando innumerables definiciones sobre la metacognición, dando unos más énfasis a unos aspectos y otros a otros, distinguiendo ambos componentes. Así, por ejemplo, Moore (1995) analiza por un lado el conocimiento metacognitivo y por otro los procesos ejecutores de control. A su vez, de Jong & Simons (1988) proponen un modelo de aprendizaje auto-regulado durante la lectura de un texto, en el cual contemplan tanto el aspecto declarativo como el aspecto procedimental, y ambos conducen a procesos de control ejecutivo como supervisión o monitorización, dirección, evaluación y reflexión, procesos que a su vez están relacionados también con orientación, planificación, ejecución y evaluación, entre otros. De esta manera, Printch (2000) también diferencia entre metacognición y regulación; y Hurme, Palonen & Järvelä (2006) distinguen asimismo entre conocimiento metacognitivo (variables referidas a la persona, a la tarea y a la estrategia) y habilidades metacognitivas (planificación, monitorización y evaluación). Por otro lado, Azevedo (2005) expone un análisis de modelos de auto-regulación, aludiendo a habilidades auto-reguladoras cognitivas y metacognitivas.

Analizando las definiciones consideradas hasta ahora, podríamos decir que, en síntesis, la metacognición puede definirse como el grado de conciencia y conocimiento de los individuos sobre sus formas de pensar (procesos y eventos cognoscitivos), y la habilidad para controlar dichos procesos para mejorar el aprendizaje.

* * *

A este respecto, nos sirve de gran ayuda tener en cuenta diferentes modelos de auto-regulación existentes, como por ejemplo, el modelo de aprendizaje auto-regulado durante la lectura de un texto (de Jong & Simons, 1988), el modelo interactivo e interdependiente (Borkowski & Turner, 1990), o el modelo cíclico de aprendizaje auto-regulado (Zimmerman, 2000).

En este contexto y a partir de un análisis de diferentes modelos de auto-regulación, Pintrich (2000) sintetiza las cuatro fases principales que dichos modelos comparten:

1. **Planificación** y establecimiento de objetivos, activación de conocimientos previos sobre la tarea, y la propia relación hacia la tarea.
2. Procesos de **monitorización** que representan conciencia metacognitiva de diferentes aspectos individuales , de la tarea y del contexto (Zimmerman & Schunk, 2001).
3. Esfuerzos de los aprendices para **controlar y regular** aspectos individuales, de la tarea y del contexto.
4. **Reacciones y reflexiones** sobre dichos aspectos individuales, de la tarea y del contexto.

Aunque estas cuatro fases siguen una **secuencia** temporal que los individuos llevan a cabo mientras realizan una tarea, no hay un supuesto fuertemente compartido por todos los modelos, sobre si las fases son jerárquica o linealmente estructuradas de manera que una tenga que suceder necesariamente a la otra. En muchos modelos, algunas de estas fases se ponen en marcha de forma **simultánea** (p.e., la monitorización, el control y la reflexión; o el hecho de que la planificación de los objetivos pueda verse alterada a partir de otros procesos de regulación). La investigación también sugiere que las fases 2 y 3 (de monitorización y de control/regulación) no encuentran muchas diferencias de procesos. De hecho, diversos estudios consideran la monitorización y el control/regulación como partes integrantes de la misma categoría de análisis de auto-regulación (p.e., Brand-Gruwel et al., 2005; Wopereis, Brand-Gruwel & Vermetten, 2008).

Además de las cuatro fases brevemente descritas y siguiendo los análisis de Pintrich (2000), los diferentes modelos también coinciden en identificar cuatro grandes **áreas** en las que la auto-regulación toma juego:

1. **Cognición**. Esta área se refiere a las diferentes estrategias cognitivas individuales que se pueden usar para aprender y realizar una tarea, así como las estrategias metacognitivas que se pueden utilizar para controlar y regular la propia cognición. Además, en esta área también se incluyen el conocimiento del contenido y el conocimiento estratégico.
2. **Motivación/afecto**. Este ámbito hace alusión a las diversas creencias motivacionales que los individuos pueden tener sobre sí mismos en relación a la tarea, tales como las creencias y valores de auto-eficacia en cuanto a la tarea. También en esta área se incluye el interés o el gusto hacia la actividad de aprendizaje, ya que ello produce una disposición positiva o negativa hacia ella y hacia el propio individuo. Asimismo, también se incluyen las estrategias que se usan para controlar y regular la propia motivación y el propio afecto.
3. **Conducta**. Este bloque se relaciona con el esfuerzo general que el individuo ejerce durante la realización de la tarea, así como la persistencia y la búsqueda de ayuda, entre otras.
4. **Contexto**. Esta última área alude a diferentes aspectos del ambiente de la tarea, de la clase en general o del contexto cultural en el cual se desarrolla la actividad. En algunos modelos, esta área no se considera objeto de auto-regulación, puesto que el contexto es externo al individuo. En tales modelos, la auto-regulación se refiere sólo a aspectos internos que la persona puede controlar o regular. Por otro lado, también es verdad que los individuos intentan controlar su entorno externo como una manera de adaptarse (Sternberg, 1985). Nuestro punto de vista es que, de acuerdo con Pintrich (2000), el aprendiz se involucra y hace uso de estrategias para controlar y regular su entorno en la medida de lo posible, y esta es un área integrante de la auto-regulación del sujeto.

Teniendo en cuenta tanto las **fases** descritas como las **áreas** diferenciadas, podemos presentar un cuadro de doble entrada en el que puede analizarse, de manera sucinta pero presumiblemente clarificadora, cómo cada una de las fases entra en juego en las diferentes áreas, y en qué aspectos concretos se incide en cada una de ellas. Existe, sin embargo, cierta dificultad en separar cada una de las celdas, por su cercanía y similitud tanto en fases como en áreas. Por ejemplo, durante el proceso de realización de una tarea, la reflexión acerca de la propia conducta llevada a cabo en términos de tiempo y esfuerzo invertidos, lleva automáticamente a realizar elecciones de determinados contextos en los cuales las tareas impliquen más o menos tiempo o esfuerzo. De todas maneras, creemos que la tabla 1 puede ayudar a detallar y, al mismo tiempo, sintetizar, los aspectos contenidos en las diferentes fases y áreas.

Tabla 1. Fases y áreas implicadas en los modelos de auto-regulación. Adaptado de Printich (2000)

	Área 1 Cognición	Área 2 Motivación	Área 3 Conducta	Área 4 Contexto
Fase 1 Planificación	-Establecimiento de objetivos -Activación de conocimientos previos -Activación de conocimiento metacognitivo	-Orientación hacia los objetivos -Valoración de la dificultad del área -Valoración de la auto-eficacia -Activación del valor de la tarea -Activación del interés por la tarea	-Prospección del tiempo y del esfuerzo -Preparación para la observación de la propia conducta	-Percepción de la tarea -Percepción del contexto
Fase 2 Monitorización	-Conciencia metacognitiva -Monitorización de la cognición	-Conciencia de la motivación y el afecto -Adaptación de la motivación y el afecto	-Conciencia y control del tiempo usado, del esfuerzo y de la necesidad de ayuda -Auto-observación de la conducta	-Conciencia y control de las condiciones de la tarea -Conciencia y adaptación de las condiciones del contexto
Fase 3 Control	-Selección y adaptación de estrategias cognitivas	-Selección y adaptación de estrategias para la dirección de la motivación y el afecto	-Aumento o disminución del esfuerzo -Persistencia -Búsqueda de ayuda	-Cambio o renegociación de la tarea -Cambio o renegociación del contexto
Fase 4 Reacción-reflexión	-Valoraciones cognitivas -Atribuciones	-Reacciones afectivas -Atribuciones	-Reflexiones sobre el tiempo y el esfuerzo invertidos	-Evaluación de la tarea -Evaluación del contexto

La delimitación de las diferentes fases y áreas propuestas por Printich (2000) nos aporta una nueva luz en cuanto a la diferencia entre metacognición y regulación, en relación a su incidencia en la resolución de problemas. Podemos considerar que, mientras la metacognición se refiere principalmente al área cognitiva, la auto-regulación puede abarcar además otras áreas como la motivación, la conducta o el contexto. Por eso, en este trabajo utilizaremos el concepto auto-regulación (o regulación), en vez del concepto de metacognición, durante el análisis del proceso de resolución de problemas.

* * *

En este apartado nos hemos centrado en analizar diferentes aportaciones teóricas para extraer de ellas elementos clave sobre el proceso de resolución de problemas. Hemos subrayado tres elementos principales apuntados comúnmente por diversos autores en diferentes épocas y desde diversas perspectivas teóricas: la importancia de los factores que influyen en la resolución de problemas, las fases clave necesarias para dicha resolución, y la importancia de la metacognición y la regulación durante el proceso. Una vez aclarados los términos metacognición y regulación, y explicada nuestra preferencia por el segundo, damos paso al siguiente apartado, en el que retomaremos estos elementos para estudiarlos más pormenorizadamente. Lo haremos, además, teniendo en cuenta otra variable importante a tener en cuenta en el proceso de resolución de problemas en la actualidad: la presencia de la información digital existente y accesible en Internet.

2. La resolución de problemas mediante el uso de la información digital

En el apartado anterior hemos tratado el proceso de resolución de problemas desde diferentes perspectivas teóricas y, analizando los puntos en los que convergían dichas aportaciones, hemos llegado a la conclusión de que existen unos factores que influyen en el proceso de resolución de problemas, que es necesario pasar por unas fases clave y que es importante tener en cuenta la regulación durante el proceso de dicha resolución. En este apartado, nos centraremos en estos puntos teniendo en cuenta además la presencia de la información digital, cuya incorporación en las vidas de los ciudadanos ha matizado los factores que afectan el proceso de resolución de problemas. En particular, ha aumentado la cantidad y el tipo de información a nuestro alcance para resolverlos, y por tanto, ha multiplicado las maneras y procedimientos para encontrarla y manejarla.

En este apartado, dedicaremos un espacio a introducir las características de información digital y cómo su presencia no sólo influye en nuestros procesos de resolución de problemas sino que además los incita, debido a que el hecho de acceder a la World Wide Web (WWW) implica en sí mismo un proceso de resolución de problemas para poder manejar la información presente en Internet. A continuación, y teniendo en cuenta el contexto y las características de la información digital, analizaremos los puntos que señalábamos al final del apartado anterior (factores, fases y regulación). Tras analizar los factores que influyen en el proceso IPS (por sus siglas en inglés, *information-problem solving*), presentaremos conjuntamente las fases (o habilidades constituyentes) y las actividades de regulación, siguiendo un modelo de resolución de problemas mediante información digital (Brand-Gruwel et al., 2005).

2.1. La información digital presente en Internet

Podemos considerar Internet como el instrumento más poderoso de información y comunicación que existe. En la WWW está disponible prácticamente toda la información sobre cualquier tópico y la velocidad con la que dicha información crece es difícil de estimar. Esta información es además inmediata, específica y exclusiva, y gran parte de la misma no se encuentra en otros lugares fuera de Internet. Por ello, se hace necesario para cualquier individuo poseer las habilidades suficientes para poder acceder a dicha información, procesarla y gestionarla. Al este conjunto de habilidades se le ha denominado *resolución de problemas mediante la información digital*, (*Information-Problem Solving*, IPS, Brand-Gruwel et al., 2005; Land & Green, 2000).

Veamos algunas características específicas de esta información digital, que la diferencian de otros medios de información (Coll, 2004; Martí, 1992; Monereo y Fuentes, 2005):

1. **Formalismo**. La información presente en Internet implica la previsión y planificación de las acciones, y el despliegue de procedimientos precisos en un orden determinado para interactuar con dicha información, así como respetar las reglas de composición o sintaxis que rigen los distintos sistemas simbólicos implicados en la representación de la información. Esta característica puede favorecer la toma de conciencia del individuo y su auto-regulación.

2. **Interactividad**. Internet permite al estudiante establecer una relación contingente e inmediata entre la información y sus propias decisiones de acceso, búsqueda y manejo de la información. Por ejemplo, un estudiante que está realizando una búsqueda de información en un motor de búsqueda de Internet, introduce unos términos o palabras clave y da la orden de búsqueda; a continuación, aparece el resultado en lo que ha sido llamada “página de resultados del motor de búsqueda” (*Search Engine Results Page*, SERP), es decir, aparece en la pantalla del ordenador una lista de las referencias que contienen los términos de búsqueda utilizados; el estudiante valora dichos resultados y, si la lista es excesivamente amplia y contiene referencias que no se corresponden con sus intereses, procede a restringir el número de términos de

búsqueda iniciales y da la orden de una nueva búsqueda, y así hasta llegar al resultado deseado.

El hecho de que Internet sea un espacio interactivo permite al usuario una relación más activa y contingente con la información, en la cual los cambios producidos en la pantalla pueden ser interpretados como una retroalimentación (*feedback*) que permite reorientar las acciones del usuario, y a la inversa. El carácter interactivo de Internet facilita la adaptación a distintos ritmos de aprendizaje y puede tener efectos positivos para la motivación y la autoestima.

3. **Dinamismo**. La WWW posee la capacidad de presentar informaciones que varían en el transcurso del tiempo, lo que permite representar los aspectos temporales de los sucesos, actividades o fenómenos. Además, Internet favorece el trabajo con simulaciones de situaciones reales y permite interactuar con realidades virtuales, lo cual favorece la exploración y la experimentación.

4. **Multimedia**. Esta característica se refiere a la capacidad que tiene la información presente en Internet de combinar e integrar diversos sistemas y formatos de representación propios de cada uno de ellos: lengua oral, lengua escrita, lenguaje matemático, sonido, imágenes fijas y en movimiento, sistemas gráficos, simulaciones, etc. Además, la Web permite también transitar con facilidad entre uno y otro formato; por ejemplo, de una fórmula física es fácil acceder a su descripción escrita, y de ésta a su ejemplificación mediante una serie de imágenes en movimiento o mediante simuladores.

   De esta manera, el carácter multimedia de Internet permite la integración, la complementariedad y el tránsito entre diferentes sistemas y formatos de representación. Ello puede facilitar a su vez la generalización del aprendizaje.

5. **Hipermedia**. Esta característica es el resultado de la convergencia de la naturaleza "multimedia" de la información presente en Internet y la utilización de una lógica "hipertextual" para la presentación de dicha información. Los sistemas y formatos tradicionales responden a una lógica secuencial y lineal, cuya máxima expresión es el "texto" escrito, y exigen un procesamiento lineal y secuencial para la adecuada comprensión de la información presentada. De hecho, los libros suelen estar escritos para ser leídos una página tras otra, un capítulo tras otro, empezando por el principio y terminando por el final. La

situación es completamente distinta en el formato basado en la hipertextualidad, cuya información no aparece organizada de acuerdo con una lógica secuencial o lineal, sino mediante conjuntos de información o "paquetes". Los lectores del formato hipertexto pueden llegar a un determinado "paquete de información" siguiendo caminos distintos. Además, debido a que no todos los paquetes interesan por igual a todos los lectores y a que existen múltiples vínculos o conexiones (*links*) entre los paquetes de información, el lector tiene la posibilidad de navegar de uno a otro, siguiendo rutas distintas en función a sus intereses concretos y particulares en un determinado momento, o a su nivel de comprensión del texto (Salmerón, Kintsch & Cañas, 2006). Aparte de la hipertextualidad, la Web ofrece también la posibilidad de navegar entre informaciones que utilizan diferentes formatos de representación, como describíamos anteriormente. De ahí el término "hipermedia" se utilice para designar este carácter de Internet.

La incidencia que puede tener la característica "hipermedia" de la información presente en Internet sobre los procesos mentales de los estudiantes es un tema abierto todavía (Pang, 1998). Para algunos investigadores del proceso IPS, la fragmentación de la información y la ausencia de una lógica secuencial en la manera de presentarla puede conducir a la superficialidad durante el acceso y procesamiento de la información encontrada en Internet, y por tanto, a la dificultad del aprendizaje (Walraven et al., 2008). Otros, en cambio, sin negar del todo el riesgo de que esto pueda suceder en ocasiones, subrayan el protagonismo que concede al aprendiz esta manera de presentar la información y las posibilidades de indagación y exploración autónoma que pone a su alcance (Rouet & Levonen, 1996; Rouet, Ros, Goumi, Macedo-Rouet & Dinet, 2011).

Internet es, pues, una telaraña con millones de páginas o documentos interconectados a través de vínculos. Así, el carácter hipermedia de Internet comporta la posibilidad de establecer formas diversas y flexibles de organización de las informaciones, y relaciones múltiples y diversas entre ellas. Todo ello puede facilitar la autonomía, la exploración y la indagación y potenciar el protagonismo del estudiante.

6. **Conectividad**. En la WWW no hay barreras de espacio ni de tiempo, permitiendo de esta manera el acceso instantáneo a la información desde

cualquier lugar y en cualquier momento. Por ejemplo, con el uso de Internet ya no resulta necesario desplazarse a un centro de recursos o a una biblioteca para consultar si existe un documento, si está disponible, o en qué año se escribió; tampoco es un requisito tener que adecuarse al horario en que dichos establecimientos estén abiertos al público. La característica de conectividad puede facilitar la diversificación, en cantidad y calidad, de las ayudas que los agentes educativos ofrecen a los aprendices.

Todas estas características sobre la información digital presente en Internet no sólo influyen directamente en el proceso IPS –debido a que dicha información y las posibilidades de interactuar con ella mediante su acceso, búsqueda, selección y organización se multiplican–, sino que al mismo tiempo incitan dicho proceso en los entornos habituales de los estudiantes, tanto escolares como de tiempo libre. Es por ello, y por la complejidad que puede llegar a suponer el proceso de resolución de problemas con el uso de la información presente en Internet, que la investigación sobre el proceso IPS se ha considerado esencial para entender sus mecanismos subyacentes y sus implicaciones para el aprendizaje.

La investigación acerca del proceso IPS ha sido descrita como una serie de tres campos de investigación "anidados", relacionados con la búsqueda de información (Wilson, 1999), como se muestra en la figura 2. Según este autor, *information behaviour* puede ser definido como el ámbito más general de investigación. *Information-seeking behaviour* consistiría en un sub-conjunto dentro de este campo, que se refiere a la variedad de métodos que emplean los individuos para descubrir y acceder a los recursos de información. A su vez, dentro de *information-seeking behaviour, information search behaviour* se correspondería con un sub-conjunto especialmente focalizado en las interacciones entre el individuo (con o sin intermediarios) y los sistemas de información basados en Internet.

En este contexto, el proceso de resolución de problemas puede ser identificado como *information-seeking behaviour* (Brand-Gruwel et al., 2005; Kuhltau, 2004), mientras que *information search behaviour* se relacionaría más bien con el proceso específico de búsqueda y localización de información.

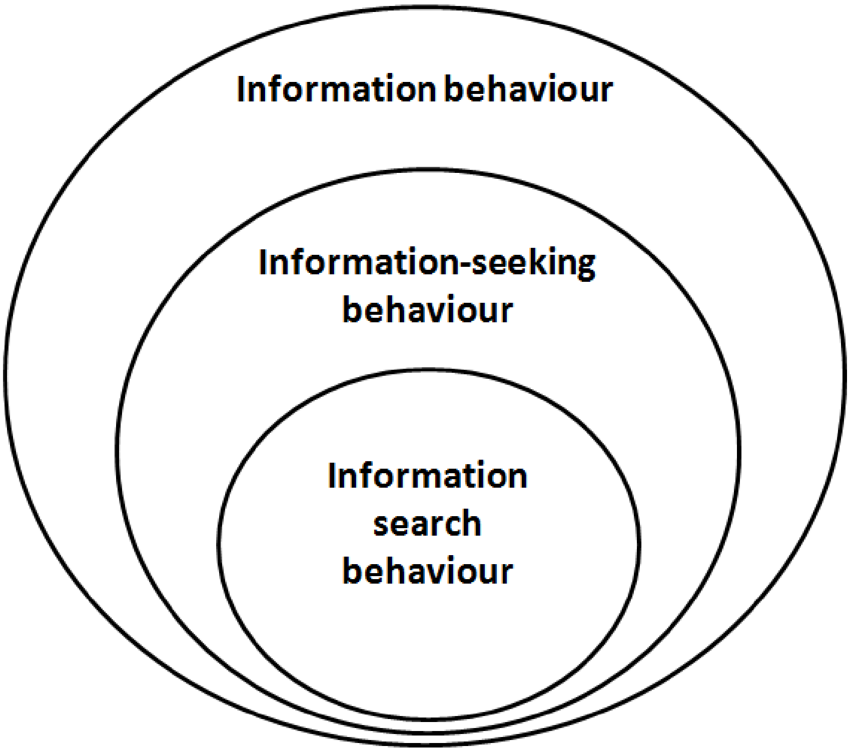

Figura 2. Modelo “anidado” de las áreas de investigación de la resolución de problemas y la búsqueda de información. Fuente: Wilson (1999)

* * *

Una vez descritas las características principales del escenario que proporciona Internet en cuanto a al tipo de información presentada (formalismo, interactividad, dinamismo, multimedia, hiperactividad y conectividad) y una vez encuadrado el campo de investigación del proceso IPS, nos focalizaremos ya en los puntos extraídos del análisis sobre la resolución de problemas del apartado anterior. De esta manera, a continuación nos centraremos en los factores que influyen en el proceso IPS y posteriormente analizaremos un modelo IPS en el cual se presentan las diferentes fases y actividades de regulación.

2.2. Factores que influyen en el proceso de resolución de problemas mediante el uso de la información digital

Nuestro punto de partida en la delimitación de los factores que influyen en el proceso de resolución de problemas surge del análisis de diferentes modelos y en la convergencia de los mismos en apuntar la necesidad de tener en cuenta diferentes tipos de factores. Así, por ejemplo, Jonassen (2007) distinguía dimensiones que incluían factores internos –características individuales como: experiencia, conocimiento declarativo, habilidades de razonamiento y creencias epistemológicas–, factores externos –sobre cómo los problemas se forman y se representan, como: complejidad, estructura y dinamismo–, y factores situacionales –las expectativas culturales y características de contexto.

Otros autores han formulado similares conjuntos de factores o variables que inciden en el proceso de resolución de un problema mediante el uso de la información digital. Las características específicas de la información presente en Internet producen un cierto cambio de óptica en la mirada de dichos factores o variables, concediendo así un mayor peso a los factores relacionados con las fuentes de información obtenidas de Internet. Así, por ejemplo, Lazonder y Rouet (2008) presentan tres conjuntos de variables que influyen en el proceso de resolución de problemas mediante la información digital. Estos conjuntos incluyen variables referidas al propio individuo, variables referidas al contexto, y variables relacionadas con los recursos de información (Rouet, 2006).

Las **variables individuales** comprenden habilidades generales tales como el nivel de aptitud del estudiante en lectura, comprensión y uso del lenguaje escrito para comunicarse. También es de gran importancia el nivel de los alumnos en conocimiento procedimental, así como su familiaridad con el tipo de recursos de información y tareas que caracterizan la situación específica del proceso de resolución de problemas al que se enfrentan (Stadtler & Bromme, 2008; Wopereis et al., 2008).

Las **variables contextuales** se refieren a todas las características relevantes de la situación –lugar, tiempo, equipos, personas y consignas–, que son preexistentes a la actividad de la resolución del problema. En un entorno escolar, el contexto de la tarea incluye a menudo las orientaciones y directrices dadas por el profesor o profesora. Estas instrucciones suelen adoptar la forma de un tema o un planteamiento del problema. Walraven et al. (2008), en su análisis sobre las dificultades de los alumnos y alumnas de diferentes edades durante la resolución de problemas mediante el uso de Internet, destacó, por un lado, la necesidad de plantear tareas realistas (y, por lo tanto, motivadoras) y, por otro, la conveniencia de mantenerlas suficientemente simples para que sean manejables por los alumnos y alumnas. Además, los enunciados complejos de las tareas pueden suponer también un problema por al menos dos razones: normalmente se requiere más conocimiento declarativo para ser bien entendidos, y son más difíciles de recordar, aumentando así la carga cognitiva o de memoria del estudiante durante el proceso de resolución del problema (Lazonder et al., 2008).

Las **variables sobre recursos de información** disponibles para el estudiante tomar cuerpo o bien en una lista preseleccionada de sitios Web, o incluso en toda la Web. Una variable importante aquí es la interfaz o las herramientas que un estudiante tenga disponible para evaluar y seleccionar fuentes potencialmente relevantes. Además, y debido a las características idiosincráticas de Internet que veíamos más arriba, se ha reconocido que estudiar documentos electrónicos puede provocar sentimientos de desorientación y sobrecarga cognitiva (p.e., Macedo-Rouet, Rouet, Epstein & Fayard, 2003). Incluso estudiando desde fuentes impresas, los estudiantes tienen una capacidad limitada para llevar a cabo su proceso de resolución de problemas a través de enormes repositorios de información (p.e., de Vries et al., 2008; Wopereis et al., 2008). Para Lazonder et al. (2008), es importante también tener en cuenta que la calidad de los dispositivos de representación de contenidos en sistemas de información electrónicos resulta crítica en la reducción de esta fuente de problemas para el estudiante.

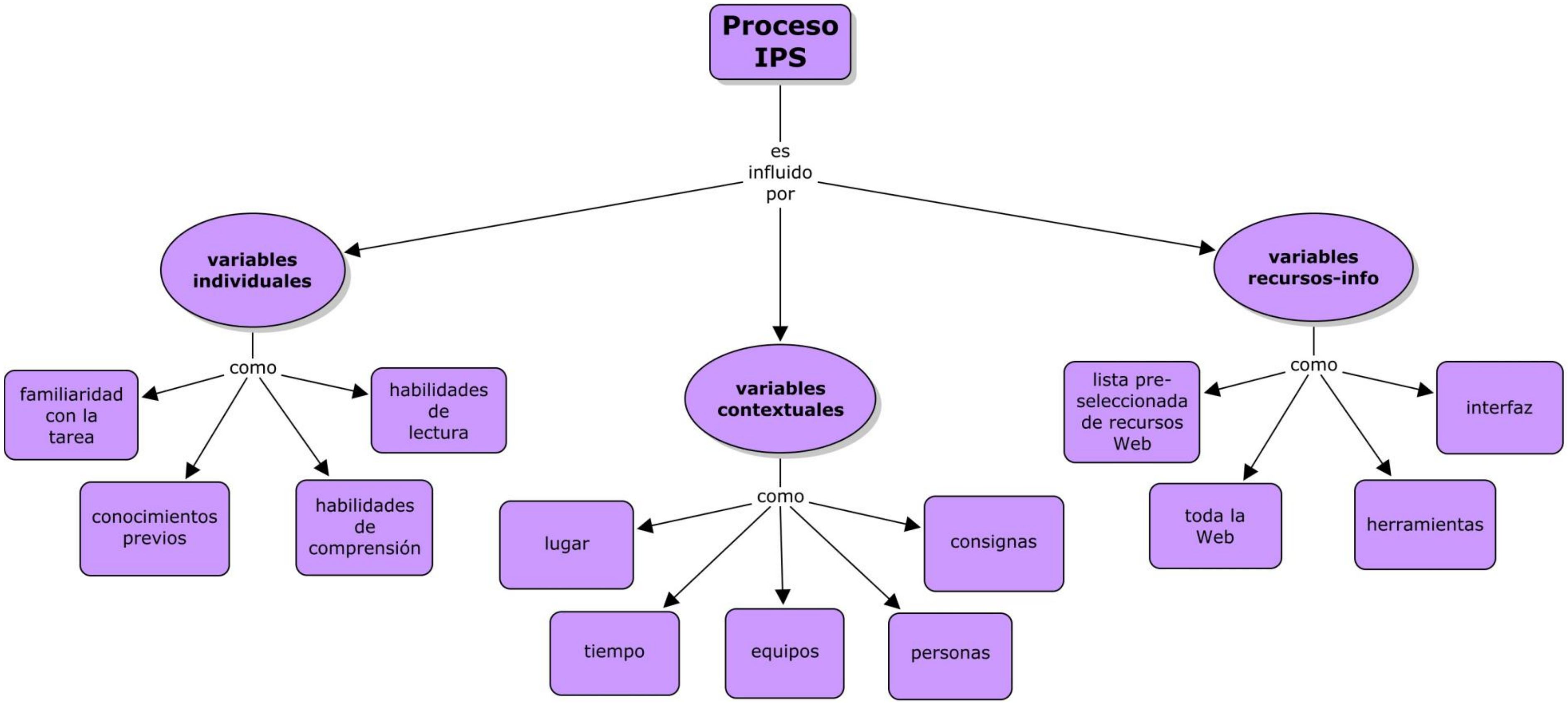

Figura 3. Conjuntos de variables que influyen en el proceso de resolución de problemas mediante información digital

La figura 3 pretende presentar un mapa formado por estos conjuntos de variables. Aunque en dicha figura no se han representado las relaciones existentes entre cada una de las variables y conjuntos, fácilmente se puede descubrir una estrecha relación entre ellas. Por ejemplo, las habilidades de lectura de un estudiante (variables individuales) pueden incidir en la manera en que él o ella interprete la consigna dada o el problema planteado, o la manera mediante la cual debe resolverse (variables del contexto). Al mismo tiempo, el número de personas implicadas en la resolución del problema planteado (variables del contexto) puede afectar la forma en la que se activen los conocimientos previos de cada individuo (variables individuales), aspecto clave para la resolución del problema y su plan para llevar a cabo dicha resolución, como ya apuntábamos en el análisis de las aportaciones teóricas en el inicio de este capítulo. Otro ejemplo de relación mutua entre conjuntos de variables podría ser el siguiente: dependiendo de los recursos disponibles –o bien una lista de páginas Web pre-seleccionadas, o bien toda la Web– (variables de recursos de información), se podrá ver afectada la duración en el tiempo de la resolución del problema (variables contextuales) y además, el estudiante tendrá que poner en marcha diferentes tipos de habilidades (variables individuales) para dar solución al problema planteado. Vemos, de esta manera, cómo los diferentes conjuntos de factores o variables se entrelazan y relacionan estrechamente, influyendo los unos en los otros, y dicha sinergia y convergencia influye a su vez en el proceso IPS y en su consecución.

* * *

Al principio de este capítulo apuntábamos tres elementos principales a tener en cuenta en todo proceso de resolución de problemas: los factores que influyen en el mismo, las fases por las que debe transcurrir el proceso y la necesidad de la regulación. En el presente apartado nos hemos centrado en el primero de estos tres puntos (los factores), llegando a la conclusión de que necesitamos tener en cuenta todo el entramado de variables que afectan al proceso de resolución de problemas cuando éste se lleva a cabo mediante la información presente en Internet. Pasemos a continuación a analizar los otros dos puntos pendientes: las fases y la regulación. Lo haremos mediante la presentación de un modelo resolución de problemas planteado por Brand-Gruwel et al. (2005), propuesto para el análisis del proceso IPS.

2.3. El modelo de resolución de problemas mediante información digital de Brand-Gruwel et al. (2005)

Para la descripción y el análisis del proceso de resolución de problemas basado en información de la Web, se han propuesto varios modelos (p.e., Blair, 2002; Clark, 2002; Brand-Gruwel et al., 2005; Gerjets & Hellenthal-Schorr, 2008; Kleinberg, 1999). En este estudio, seguimos el modelo presentado por Brand-Gruwel et al., (2005), que a su vez ha sido construido sobre las bases del modelo de Eisenberg y Berkowitz (1990). Hemos considerado este modelo como el más adecuado para describir y analizar el proceso IPS debido a que se basa en los supuestos fundamentales que recogíamos de las aportaciones teóricas al comienzo de este capítulo (los factores, las principales fases y las actividades de regulación), y a que los ha conjugado adaptándose clara y adecuadamente a la idiosincrasia de la información presente en Internet. El modelo de Brand-Gruwel et al. (2005) ha sido además ampliamente considerado en la investigación en procesos IPS por diferentes autores y perspectivas (p.e., Aula & Nordhausen, 2006; Braten et al., 2011; Coley et al., 2007; van Deursen & van Dijk, 2010; Lazonder & Rouet, 2008; Kienhues et al., 2011; Mason et al., 2010; Raes et al., 2011; Tatcher, 2008; Walraven et al., 2008; Wittwer & Senkbeil, 2008; Wopereis & van Merriënboer, 2011).

El modelo IPS propuesto por Brand-Gruwel et al. (2005) ha desarrollado y considerando procesos cognitivos que engloban, por un lado, habilidades cognitivas constituyentes y sub-habilidades (a modo de fases y sub fases), y por otro lado, actividades de regulación; unas y otras involucradas en procesos de resolución de problemas basados en la Web (Figura 4).

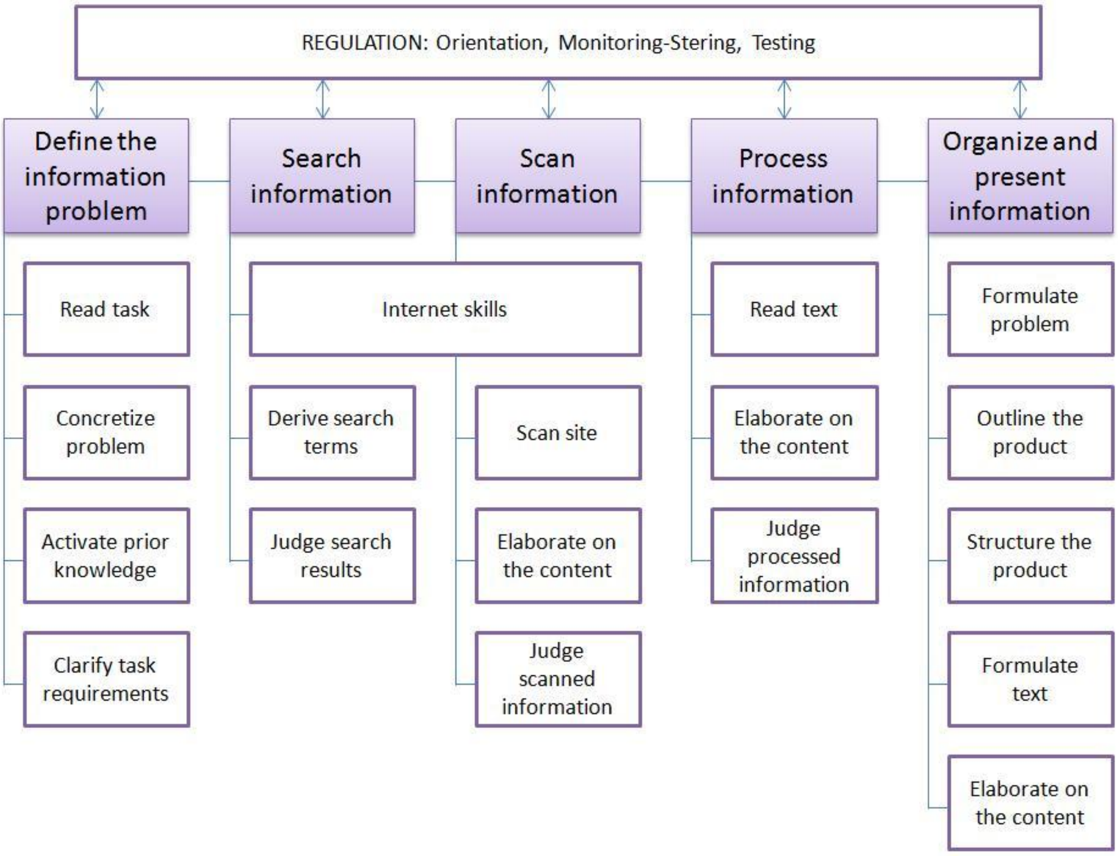

Figura 4. Modelo de resolución de problemas mediante el uso de information digital (Brand-Gruwel et al., 2005)

Aunque este modelo tuvo su origen en la perspectiva teórica del procesamiento de la información, sería difícil clasificarlo completa y únicamente en dicha teoría, debido a que se encuentra impregnado de elementos provenientes de otras perspectivas teóricas. Así, por un lado, encontramos que sus habilidades constituyentes y sub-habilidades tienen una fuerte base cognitiva, hasta el punto de denominarse "habilidades cognitivas" (perspectiva de la ciencia cognitiva) y, por otro, a lo largo del proceso IPS existen elementos que remiten al supuesto de que el aprendizaje se construye activamente mediante la relación e integración de los nuevos conocimientos en los conocimientos previos (perspectiva constructivista).

En este modelo, el primer paso consiste en crear una representación interna del problema. Posteriormente, tiene lugar la búsqueda de información, con fases de exploración rápida y de exploración más sistemática, en el estudio de la profundidad de los materiales o fuentes encontrados. Una habilidad crítica en este modelo de resolución de problemas es la necesidad de que los estudiantes evalúen la pertinencia de la información encontrada, para lo cual necesitan comparar y evaluar la información teniendo en cuenta la representación inicial del problema efectuada al inicio del proceso o reconstruida durante el mismo. Finalmente, una vez que se ha encontrado información relevante, el estudiante tiene que transformar la información y adaptarla al problema propuesto inicialmente para dar respuesta al mismo. Aunque estas fases se desarrollan de manera secuencial, ello no impide que pueda haber algún retroceso durante el proceso, haciéndose éste interactivo y bidireccional (Kuiper, Volman & Terwel, 2008; Lazonder & Rouet, 2008; Wopereis et al., 2008). En los apartados siguientes, explicamos más extensamente este modelo y sus procesos cognitivos implicados: por un lado, habilidades constituyentes (*constituent skills*) y sub-habilidades (*sub-skills*), y por otro, actividades de regulación.

2.3.1. Constituent skills, sub-skills

Definición del problema. El proceso de resolución de problemas mediante información digital se inicia con el reconocimiento sobre la necesidad de información. La definición del problema será comprensiva cuando se dé una clara descripción del problema y del tipo y de la cantidad de información que se precisa para resolverlo. Según el modelo de Brand-Gruwel et al. (2005), la definición del problema siempre tendrá lugar al inicio del proceso IPS. Para que haya una buena representación del problema, serán necesarias las siguientes sub-habilidades: (a) *lectura de la tarea*, (b) *concretización del problema* a ser resuelto, mediante preguntas y sub-preguntas bien formuladas, (c) *activación de los conocimientos previos* en la memoria del individuo, para así facilitar la integración de la nueva información en los conocimientos que ya posee el individuo (Hill, 1999; Moore, 1995), y (d) *clarificación de los requisitos de la tarea* a llevarse a cabo.

Búsqueda de la información. Una vez el problema ha sido formulado, hay que acceder a las fuentes de información para resolverlo, mediante un plan o una estrategia de búsqueda. El principal objetivo de la habilidad constituyente de la "búsqueda de información" consiste en seleccionar fuentes interesantes y obtener una visión general de los resultados de búsqueda. En esta habilidad pueden considerarse diferentes sub-habilidades.

La primera de ellas consiste en un conjunto de habilidades sobre Internet (*Internet skills*), diferenciadas por van Deursen (2010) en dos grupos: (1) *operational Internet skills* –tales como acceder a un navegador de Internet o utilizar un motor de búsqueda– y (2) *formal Internet skills* –navegar mediante el uso de hipervínculos representados mediante diferentes formatos o mantener el sentido de orientación al navegar por la red.

La segunda sub-habilidad que se necesita para llevar a cabo de una manera adecuada la habilidad de búsqueda de información en Internet, consisten en *especificar términos de búsqueda* en un motor de búsqueda, acción que se verá influida por la manera en que llevó a cabo la previa habilidad constituyente –definición del problema, y en concreto, el análisis de la información requerida para resolverlo.

La tercera sub-habilidad consiste en *evaluar los resultados* obtenidos por el motor de búsqueda en cuanto a calidad, relevancia y fiabilidad. Los criterios necesarios para dicha evaluación también dependerán de la previa definición del problema. Walraven et al. (2009) analizaron los criterios utilizados por estudiantes para evaluar resultados de búsquedas y los diferenciaron en cuanto a *relevancia* y *fiabilidad*; de esta manera, la relevancia se refiere al contenido de la fuente de información, a su lenguaje, a su estructura, a la cantidad de información contenida, etc., y la fiabilidad está relacionada con el autor de la fuente, sus atributos, las referencias de la página, si se trata de una fuente primaria o secundaria, su objetividad, su objetivo, etc.

Escaneo de la información. El principal objetivo de esta habilidad constituyente del proceso de resolución de problemas mediante el uso de información de Internet, consiste en explorar el sitio web encontrado y evaluar la información hallada en el mismo en cuanto a los criterios anteriormente señalados de relevancia y fiabilidad, para así poder decidir si la información puede ser útil para a dar respuesta al problema planteado, a la luz de los requisitos del producto final esperado. Al explorar el sitio web, tendrá lugar la elaboración del contenido, que consistirá en combinar la nueva información explorada con los conocimientos previos o con otras informaciones encontradas. De esta manera, las sub-habilidades necesarias durante el escaneo de la información son, aparte de las habilidades de Internet a las que hemos hecho mención en el párrafo anterior, la *exploración del sitio web*, la *elaboración del contenido* y la *evaluación de la información explorada*.

Procesamiento de la información. Esta habilidad consiste en analizar más pormenorizadamente la información encontrada. Es decir, la información se selecciona, se analiza en profundidad, se relaciona con los conocimientos previos, y se reestructura para obtener de ella una comprensión profunda. Por eso, las sub-habilidades como *leer el texto*, *elaborar su contenido* teniendo en cuenta los conocimientos previos y la respuesta que se espera para dar solución al problema planteado, y *evaluar la información procesada* en cuanto a relevancia y fiabilidad, serán clave. El objetivo principal del procesamiento de la información en este proceso de resolución de problemas consiste en conseguir la comprensión de la información, lo cual implica integrar las diferentes piezas de información encontradas entre ellas y con los conocimientos que previamente ya se tenían, para poder dar una adecuada respuesta al problema.

Organización y presentación de la información. La habilidad de organizar y presentar la información se refiere a la síntesis de la información necesaria para la obtención de un producto. El tipo o la forma del producto obtenido dependerá de la tarea a realizar: informes, artículos, cartas, presentaciones, etc. A pesar de que los tipos de productos difieren, el proceso que conduce a su realización se concreta de manera similar. Este proceso se caracteriza por ser estructurado e interactivo y consiste en organizar, reorganizar y plasmar la información encontrada para solucionar el problema inicialmente planteado. Durante este proceso, las sub-habilidades más relevantes son las siguientes: *formulación y reformulación del problema* de manera clara, independientemente del tipo de producto que se requiera; *esbozo del producto*, a modo de esqueleto o esquema a seguir: *estructuración de dicho producto*, dándole forma y contenido; *formulación y elaboración del texto* que definitivamente dará el contenido al producto; y *elaboración del contenido*, que tendrá lugar a lo largo de este proceso.

2.3.2. Actividades de regulación

Como hemos visto en apartados anteriores, la regulación desempeña un papel esencial en la coordinación del proceso de resolución de problemas mediante el uso de la información digital. También hemos ido apreciando que se han formulado diversas clasificaciones sobre las actividades de regulación (p.e., de Jong & Simons, 1988; Vermunt, 1995). Basándose en investigaciones de de Jong y Simons (1988) sobre la resolución de problemas, el modelo propuesto por Brand-Gruwel et al., (2005) considera un conjunto de actividades de regulación: **orientación** hacia una tarea o un problema, **dirección**, **monitorización** del proceso y **evaluación** del proceso y del producto.

Orientación. La orientación hacia una tarea incluye tanto el análisis de la tarea como el desempeño de la misma. Durante la orientación hacia la tarea, se tiene en cuenta la situación actual, se analiza la tarea y se considera y reconsidera el producto solicitado. También se examina el tiempo necesario y disponible en cada momento para la realización de la tarea. Se tienen en cuenta también los conocimientos previos y propia competencia.

Dirección. Una vez se ha realizado la orientación, puede tomarse una decisión bien fundada sobre cómo llevar a cabo la tarea o las diferentes sub-tareas. La dirección se centra en la decisión sobre qué actividades tienen que realizarse. La dirección se produce a un nivel macro (p.e., una planificación general del proceso de resolución del problema) y a un nivel micro (p.e., decidir qué hacer a continuación).

Monitorización. Monitorizar o supervisar el proceso de la resolución del problema significa que mantener "*an eye on task performance*" (Brand-Gruwel et al., 2005) o, como expresaron los propios de Jong y Simmons (1988), "*the finger on the pulse*". Este proceso parece ser menos profundo que la orientación hacia una tarea. En la propuesta de Brand-Gruwel que tomamos como modelo de resolución de problemas, las actividades dirección y monitorización son agrupadas en la misma actividad, quedando por tanto dirección-monitorización.

Evaluación. La evaluación pretende valorar procesos y productos. Cuando esto se realiza durante la ejecución de la tarea, recibe el nombre de *formativa*. En el caso de que la evaluación de procesos y productos se lleve a cabo al final del proceso de resolución del problema, recibe el nombre de *sumativa*. La evaluación sumativa también es relevante para ajustar el desempeño futuro.

* * *

El modelo IPS propuesto por Brand-Gruwel et al. (2005) nos ofrece un marco en el que apoyarnos para la descripción y análisis de los procesos de resolución de problemas basados en la información Web presente en Internet. Hemos descrito las habilidades y sub-habilidades que el modelo propone que sean efectuadas a modo de fases, así como las actividades de regulación que intervienen a lo largo de todo el proceso y lo enriquecen.

Sin embargo, diferentes investigadores coinciden en afirmar que estas habilidades y actividades de regulación no son desarrollados instintivamente por parte los estudiantes, sino que, más bien al contrario: son procesos que deben ser aprendidos y perfeccionados (Puustinen et al., 2009; Wood, 2009). Estudiantes y usuarios de distintas edades y características poseen escasas habilidades este tipo (Ladbrook & Probert, 2011) y enfrentan muchos problemas cuando se expone a una tarea IPS. En el apartado siguiente describiremos cada una de las dificultades que han sido reportadas por la investigación en el campo de la IPS. Lo haremos siguiendo el mismo modelo, y sus correspondientes habilidades constituyentes, sub-habilidades y actividades de regulación.

3. Dificultades encontradas en el proceso de resolución de problemas mediante información digital

Después de describir el modelo de análisis del proceso de resolución de problemas basado en información digital propuesto por Brand-Gruwel et al. (2005) y de analizar sus elementos principales, aparece la necesidad de examinar qué tipo de dificultades encuentran los alumnos y alumnas de las diferentes edades al enfrentarse a este tipo de problemas. Estas dificultades van impregnando la totalidad del proceso IPS, tanto en lo que se refiere a sus habilidades constituyentes (*constituent skills*) –definición del problema, búsqueda de información, escaneo de la información, procesamiento de la información, y organización y presentación de la información– como en lo que concierne a las diferentes actividades de regulación (*regulation activities*) –orientación, dirección, monitorización y evaluación.

En este apartado recogemos y relacionamos las aportaciones teóricas de diferentes estudios sobre el proceso IPS en diferentes ámbitos, características y edades, con el fin de obtener una visión más amplia de las dificultades existentes durante el proceso de resolución de problemas mediante el uso de información digital.

3.1. Dificultades en el proceso de resolución de problemas: *constituent skills, sub-skills*

En este apartado nos centraremos en las dificultades encontradas en el proceso de resolución de problemas mediante información digital (IPS) en cuanto a las habilidades constituyentes (*constituent skills*) y a las sub-habilidades (*sub-skills*).

Definición del problema. Siguiendo los análisis revisados realizados por Walraven et al (2008), los adultos no suelen tener problemas con la habilidad de constituyente "definición del problema". Sin embargo, los adolescentes encuentran bastantes dificultades con la formulación de preguntas (Wallace, Kupperman, Krajcik & Soloway, 2000), la 'activación de sus conocimientos previos', la 'clarificación de los requisitos de la tarea' y la 'determinación de la información necesaria' (Walraven et al, 2008). Cuando los estudiantes no tienen una representación clara de sus conocimientos previos, es más difícil que los relacionen con los nuevos que van a encontrar durante la resolución del problema y por tanto que integren nuevos conocimientos, dificultad que suele ocurrir (Land & Hannafin, 1997; Moore, 1995). La mayoría de los adolescentes empieza a buscar inmediatamente, sin explorar previamente el tema, sin planificar de manera consciente su búsqueda o sin reflexionar sobre la tarea a llevar a cabo (Fidel et al., 1999). Poco es conocido acerca de los niños y sus problemas con esta habilidad constituyente, pero teniendo en cuenta las dificultades que tienen los adolescentes, es fácil imaginar los que puedan tener los menores que ellos, de acuerdo con Walraven et al. (2008).

Búsqueda de la información. La mayoría de los problemas en la habilidad constituyente "búsqueda de la información" se produce con las sub-habilidades 'especificación de los términos de búsqueda' y 'evaluación de los resultados de la búsqueda'. Niños, adolescentes y adultos jóvenes no siempre saben qué términos utilizar para su búsqueda en Internet (Bilal, 2000; MaKinster, Beghetto & Plucker, 2002; Wallace et al., 2000). Los estudiantes suelen hacer búsquedas libres cuando navegan en entornos hipermedia, en lugar de tener un objetivo específico de aprendizaje (Azevedo, Cromley & Seibert, 2004). En la misma línea, Hsieh-Yee (2001) encontró que los niños generalmente no buscan sistemáticamente, prefieren navegar sin un rumbo fijo y tienen dificultades para escribir los términos de búsqueda, formular cuestiones para su búsqueda o juzgar la pertinencia de los sitios Web.

Además, dicha 'evaluación de los resultados de la búsqueda' no se suele realizar de una manera sistemática. Personas de todas las edades no siempre se basan en una evaluación válida de los resultados obtenidos en la SERP para seleccionar sus resultados y acceder a ellos. La fuente de la que proviene el sitio Web no es siempre cuestionada y la opción para abrir un sitio, en su mayoría es guiada por el título o el resumen del sitio. Sin ningún trabajo preparatorio sobre los objetivos de búsqueda, los estudiantes tienden a seleccionar sitios Web que parecen pertinentes basándose en indicadores superficiales (Rouet et al., 2011).

Escaneo de la información. Según algunos investigadores, el mayor problema durante el "escaneo de la información" es que la evaluación del sitio Web se realiza basándose en la información esperada y no en aspectos como la validez, la autoría y la actualidad de las páginas. Los adultos parecen tomarse su tiempo para escanear en primer lugar y, a continuación, procesar la información. Al preguntarles qué fuentes utilizaban, los usuarios adultos del estudio de Rosell-Aguilar (2004) dijeron que ellos consultaban fuentes de confianza como la página de la Universidad, los periódicos locales, etc., analizando minuciosamente las páginas, siguiendo enlaces, y utilizando así múltiples fuentes de información. Monereo, Fuentes y Sánchez (2000) informaron que la mayoría de los adultos encuestados mediante su cuestionario tenía gran confianza en la credibilidad de la información que habían encontrado. Además, los resultados de Brand-Gruwel et al. (2005) revelaron que los buscadores expertos adultos juzgaban la calidad y pertinencia de la información y la fiabilidad de las fuentes más a menudo que los buscadores principiantes. Por otro lado, los adolescentes presentan problemas para separar materiales acreditados y cuestionables, y encuentran problemas con la selección y evaluación de la información (Lorenzen, 2002). Suelen usar información que podría responder a su pregunta, incluso si el sitio es de un origen comercial y no destinado a la divulgación de conocimiento científico (Fidel et al., 1999).

Durante el proceso de "escaneo de la información" y tras evaluar la fuente y la información, el contenido relevante encontrado debería ser almacenado (Walraven et al., 2009). La mayoría los buscadores jóvenes no suele almacenar dicha información. Simplemente, cuando una fuente les parece útil después del escaneo inicial, el sitio se lee en profundidad y la información se procesa (Walraven et al., 2008).

Procesamiento de la información. De acuerdo con diversos estudios, los niños en edad escolar rara vez se toman el tiempo suficiente para leer un sitio Web en profundidad (Kafai & Bates, 1997; Schacter et al., 1998; Wallace et al., 2000). También tienden a evaluar la información encontrada teniendo en cuenta sólo las palabras que esperaban encontrar. Wallace et al. (2000) afirmaron también que algunos niños pequeños '*never read enough of the page to understand that its content had nothing to do with their question, and they used it as evidence that they had finished their* *assignment*' (p. 94). Las habilidades de lectura desarrolladas por escolares en entornos hypermedia han resultado ser de gran importancia, hasta el punto de predecir la selección de links durante el procesamiento de la información Web (Salmerón & García, 2011).

Otros estudios (por ejemplo, Britt & Angliskas, 2002; Cerdán & Vidal-Abarca, 2008; Rouet & Coutelet, 2008) señalan las dificultades de los estudiantes al preguntárseles sobre cómo encontrar información relevante y fiable de documentos impresos o documentos Web. Los adolescentes también presentan este tipo de problemas al resolver un problema basado en información digital en Internet (Walraven et al., 2008).

Los buscadores adultos expertos en el estudio de Brand-Gruwel et al. (2005) pasaban más tiempo en la elaboración del contenido que los principiantes. En la misma línea, Goldman (2011) encontró que una diferencia entre los buenos y malos estudiantes radicaba en el tiempo de permanencia en un sitio Web: los buenos estudiantes pasaban más tiempo en sitios Web fiables y relevantes, mientras que en los malos estudiantes no se encontró ninguna diferencia.

Walraven et al. (2008) señalaron que la cuestión acerca de la dificultad durante el procesamiento de información yacía en el hecho de que Internet se compone del *HyperText Markup Language* (HTML), el cual permite que en un documento existan vínculos a otros documentos y así sucesivamente, como señalábamos en apartados anteriores al tratar las características de la información digital presente en Internet. Según Rouet y Levonen (1996), precisamente la lectura de hipertexto tiene sus ventajas, por ejemplo: el acceso a la información extra entraña mayor facilidad en un entorno de hipertexto; sin embargo también tiene sus inconvenientes: es mucho mayor el riesgo de desorientación, y además el procesamiento de la información en entornos hipertextuales supone una mayor carga cognitiva para sus usuarios. Las demandas cognitivas de la lectura de menús en comparación con los textos convencionales implican por parte de los usuarios el aprendizaje de estrategias específicas de lectura para un uso eficaz de los menús en Internet (Rouet et al., 2011). Sin embargo, dotando a los estudiantes de estructuras y habilidades coherentes en el manejo de los menús se les puede ayudar en gran medida a superar esos tipos de problemas (Rouet & Levonen, 1996).

Organización y presentación de la información. Brand-Gruwel et al. (2005) mencionaron que expertos y principiantes adultos pasaban una cantidad igual de tiempo en esta fase, pero los expertos prestaban más atención a la formulación y reformulación del problema. En cuanto a las estrategias para recopilar la información encontrada en la WWW, los estudiantes en general utilizan predominantemente estrategias ineficaces, como copiar información desde el entorno hipermedia a sus notas (Azevedo et al., 2004). Raes et al. (2011) también observaron el frecuente uso de la función 'copiar y pegar' en estudiantes de secundaria, quienes incluían fragmentos de texto extraídos directamente de Internet en sus respuestas. Además, los mismos autores señalaron que los estudiantes tienden a reducir la totalidad de la tarea en el hecho de encontrar una respuesta obvia en un determinado sitio Web, prestando así menos atención al pensamiento crítico y a la reflexión sobre el contenido de la información tratada (Raes et al, 2011).

Como se ha podido ir apreciando a lo largo de este espacio sobre las dificultades encontradas en las habilidades constituyentes y sub-habilidades durante la resolución de un problema mediante el uso de la información digital de Internet, podríamos resumir que los usuarios de las diferentes edades generalmente presentan abundantes dificultades. Especialmente la gente joven –adolescentes y niños– se enfrentan con problemas en casi cada una de las habilidades y sub-habilidades descritas.

3.2. Dificultades en el proceso de resolución de problemas: actividades de regulación

Como hemos ido viendo desde el inicio de este capítulo, son muchos los autores que coinciden en atribuir a la metacognición un papel fundamental en la realización de actividades basadas en la Web, pues, si los estudiantes no regulan su aprendizaje cuando están usando entornos hipermedia, éstos pueden llegar a la conclusión de que dichos entornos son inefectivos de manera inherente, cuando en realidad lo que se necesita es fomentar la regulación en los aprendices al usar este tipo de entornos, potentes pero complejos al mismo tiempo (Lazonder, 2005).

El proceso de resolución de problemas mediante el uso de la información digital es un proceso lleno de complejidad que requiere que los estudiantes presten atención a muchas variables simultáneamente, con lo cual, deben estar constantemente supervisando-controlando sus resultados y regulando su conducta (Moore, 1995). De acuerdo con Lee & Baylor (2006), los alumnos deberían auto-regularse para poder monitorizar y evaluar sus propios procesos, y usar las estrategias adecuadas para resolver adecuadamente sus tareas a través de procesos de regulación.

Hirsch (1999) encontró que los niños participantes en su estudio no realizaban ningún seguimiento de cómo buscaban información, ni de las URLs útiles, ni de sus consultas de búsqueda. Otros estudios apuntaron que los adolescentes no sentían la necesidad de planificar una búsqueda o de comprobar si su planificación estaba funcionando (Fidel et al., 1999; Lyons et al., 1997). Sin embargo, eran conscientes del hecho de que su ortografía en direcciones URL y en los términos de búsqueda podía influir en los resultados de dicha búsqueda (Fidel et al., 1999).

Según Walraven et al. (2008), los adultos que pueden clasificarse como buscadores estratégicos o exitosos muestran signos de orientación, supervisión, dirección y evaluación. En cambio, los buscadores no estratégicos son menos eficaces y no regulan su proceso de búsqueda (MaKinster et al., 2002; Monereo et al., 2000). En esta línea, Brand-Gruwel et al. (2005) encontraron también que los expertos adultos dirigían y monitorizaban su proceso más a menudo que los principiantes. El papel de la auto-regulación, además, se ha mostrado como un potente factor influyente en las estrategias de selección de hipervínculos y en la comprensión de textos en entornos hipermedia (Salmerón, Kintsch, & Kintsch, 2010).

Concluyendo, los estudiantes de todas las edades tienen problemas con la regulación, de manera semejante a como ocurría con las habilidades constituyentes y sub-habilidades descritas y analizadas anteriormente. Además, las dificultades en la regulación adquieren una gran relevancia, debido a que la calidad del proceso IPS está influenciada por su capacidad de regulación, pues tanto los niños y adolescentes como los adultos mejoran sus procesos IPS cuando los orientar, dirigen, monitorizan y evalúan.

* * *

Iniciábamos este capítulo analizando diferentes aportaciones teóricas sobre el proceso de resolución de problemas y determinando tres principales puntos a tener en cuenta para describir y analizar el proceso de resolución de problemas mediante la información digital (proceso IPS): factores que influyen en el proceso, fases necesarias para resolverlo y actividades de regulación relacionadas con dicho proceso. Posteriormente añadimos el elemento de la información presente en Internet y sus características específicas, el cual nos sirvió asimismo como pilar sobre el que apoyarnos para considerar el proceso IPS. A partir de ahí, analizamos cada uno de esos tres puntos: por un lado, los factores o variables que inciden en el proceso IPS –las variables individuales, las contextuales y las referentes a los recursos de información– y por otro, las fases y actividades de regulación –o procesos cognitivos involucrados en el proceso IPS.

De esta manera, hemos ido analizando dichas fases y actividades reguladoras siguiendo el modelo IPS de Brand-Gruwel et al. (2005), que las integra y les da sentido a lo largo de todo el proceso de resolución de problemas mediante la información presente en la Web. Finalmente, y basándonos en dicho modelo, hemos ido apuntando y describiendo las diversas dificultades que la mayoría de los aprendices encuentran en cada una de las fases o habilidades, así como en las actividades de regulación.

Tanto el modelo IPS trabajado en este capítulo como las dificultades a las que se encaran los estudiantes al resolver un problema utilizando información digital, serán retomados en siguientes capítulos de esta disertación. En concreto, en el capítulo 3, que sigue a éste, estudiaremos cómo el modelo IPS ha sido llevado a la educación y a la instrucción, es decir, de qué maneras se ha integrado en diversas metodologías de enseñanza-aprendizaje y de qué modalidades se han desarrollado procesos de instrucción para ayudar a estudiantes y usuarios a resolver problemas basados en la Web, superando sí los desafíos a los que se enfrentan.

Chapter 3. Learning and instruction in Information-problem solving

In the 2nd chapter of this dissertation, we analysed theoretical contributions about how regular people and students perform the process of problem solving. This process is affected by several factors or variables: internal variables, contextual variables, and information source variables. The later is a set of critical variables, in particular when the problem-solving process occurs using digital information on the Web (Information-Problem Solving, or IPS). The IPS model suggested by Brand-Gruwel et al. (2005) was presented and described, following its constituent skills, sub-skills, and regulation activities involved in an IPS process. In addition, many difficulties in accomplishing this process are found in several skills and regulation activities, in persons from all the ages.

For this reason, one of the main objectives of this dissertation is to deeply analyse those kinds of difficulties, specifically the difficulties that secondary students find when executing problem-solving cognitive processes while learning curricular contents at school. The other main objective of this dissertation is to analyse the incidence of an IPS instructional process carried out in secondary classrooms. In this chapter, we present two important sources that suppose the basis to describe our IPS instructional proposal.

The first source that fosters our IPS instruction is the analyses of the learning and teaching methods that involve problem-solving processes and are based on constructivist principles. All of these methods consider students as the protagonists of their own learning process, and involve a rich methodological structure to perform problem-solving processes at school. Those methods are the following: Inquiry-based Learning (IBL), Case-based Learning (CBL), Problem-based Learning (PBL), Project-based Learning (PjBL), and Challenge-based Learning (ChBL). We based our instructional proposal on their features and methodological issues.

The second source that feeds our proposal is the analyses of the research studies that reported the characteristics and the impact of IPS instruction in students. In particular, our interest will be focussed in the IPS instruction embedded in the academic curriculum (contrary to the instruction isolated from the curricular context) and in the studies that report findings of instruction in Secondary Education.

In this chapter, first we present and analyse a set of teaching and learning methods that involve problem-solving processes. Second, we analyse research studies on IPS instruction carried out to improve information-problem solving skills in students, especially in Secondary Education. Third, we describe our methodological and instructional proposal, based on the analyses of the previous (first and second) sections.

3.1. Teaching and learning methods involving Information-problem solving processes

3.1.1. Inquiry-based learning

Inquiry-based learning (IBL) (Enquiry-based learning in British English) is defined as “an approach to learning that involves a process of exploring the natural or material world, and that leads to asking questions, making discoveries, and rigorously testing those discoveries in the search for new understanding” (Natural Science Foundation, 2000: 2). In this approach, students adopt a scientific role and make their own discoveries; they generate knowledge by activating and restructuring their knowledge schemata (Mayer, 2004). Inquiry learning environments also ask students to take initiative in the learning process and can be offered in a naturally collaborative setting with realistic material (de Jong, 2006).

The idea of inquiry, or discovery, has roots in Socratic inquiry and centuries-old apprenticeship training. Socrates did not lecture, but he moderated and directed questioning, by guiding his students through inquiry to answer their own questions, search out answers to problems, and relate their knowledge to life applications (Plato, 360 B.C.E./1960). More recently, inquiry as a methodological approach also has a long history (Bruner, 1961; Dewey, 1938; Freire, 1984; Piaget, 1964; Vigotsky, 1978). IBL is an instructional method developed during the discovery learning movement of the 1960s. It was developed in response to a perceived failure of more traditional forms of instruction. The teacher does not begin with a statement, but with a question.

IBL has been of great influence in science education, where it is known as inquiry-based science. The process of IBL mimics authentic inquiry as they share the following constitutive processes: **orientation** (identification of variables and relations);

hypothesis generation (formulation of a statement or a set of statements); **experimentation** (changing variable values, making predictions, etc.); **drawing conclusions** (based on the validity of the hypotheses); **evaluation** (by reflecting on the knowledge developed and the learning process); **planning** (outlining a schedule for the inquiry process); and **monitoring** (maintaining an overview of the process and the knowledge that is being developed). However, IBL and authentic inquiry have some differences, such as the origin of the research question, the number of (known) variables, and the presence of flaws in data (Chinn & Malhotra, 2002).

It has been suggested by researchers (Banchi & Bell, 2008; Herron, 1971; Schwab, 1962) that there are four levels of IBL in science education: confirmation inquiry, structured inquiry, guided inquiry and open inquiry. With *confirmation inquiry*, students are provided with the question and procedure (method), and they confirm a principle through an activity when the results are known in advance; confirmation inquiry is useful when a teacher's goal is to reinforce a previously introduced idea, to introduce students to the experience of conducting investigations, or to engage students to practice a specific skill, such as collecting and recording data.

The second level of inquiry, *structured inquiry,* asks students to investigate a teacher-presented question through a prescribed procedure; it means that the question and procedure are still provided by the teacher, but students generate an explanation supported by the evidence they have collected.

In *guided inquiry*, the teacher provides students with only the research question and students investigate the teacher-presented question using student designed/selected procedures to test their question and the resulting explanations. This kind of inquiry is more involved than structured inquiry, so that it is most successful when students have had numerous opportunities to learn and practice different ways to plan experiments and to carry out a data collection process.

The fourth and highest level of inquiry is *open inquiry.* In this level, students investigate questions that are formulated through student designed/selected procedures; they have the purest opportunities to act like scientists, by deriving questions, designing and carrying out investigations, and communicating their results. This level requires the most scientific reasoning and greatest cognitive demand from students.

Nowadays, technological developments can implement more effective inquiry learning. For example, using simulations to model a phenomenon or process, students can perform experiments by changing variables (such as resistances in an electrical circuit) and then observe the effects of their changes (e.g., the current). In this way, students (re-)discover the properties of the underlying model (in this case, Ohm's law). This new version of IBL has been called Inquiry-Web Learning (IWL).

3.1.2. Case-based learning

Case-based learning (CBL) is a learning method based on constructivism theories (Vygotsky, 1978), and experiential learning theories (Dewey, 1953; Kilpatrick, 1918; Kolb, 1984). CBL involves a case description of an actual situation, in which a person is confronted with the need to make a decision regarding a particular challenge, opportunity, problem, or issue (Barnes, Christensen, & Hansen, 1994). In CBL, a case presents a specific situation, event, or problem in order to expose students to complex, varied experiences. The case is usually introduced in a narrative style; it can be taken from real life or constructed in a realistic way.

The idea of teaching and learning from cases, stories or tales, also goes back many centuries ago with Christian parables or the popular traditional fables involving a moral or teaching to be applied to life itself. Through the years, this style has been evolving towards more systematic methods to be used in formal education.

The main objectives of CBL are that students might be actively engaged in the elaboration of proposals to analyse the case and, eventually, to promote possible, valid solutions to the case. CBL enables students to step into the role of the decision maker (Pearce, 2002). It is expected that students experience the complexity, uncertainty, ambiguity, and contradictions that usually are present in the analyses of cases in real contexts. Cases provide a mechanism by which students can become intimately involved in real-world situations and take ownership, feel the pressure, and recognize the risks of exposing their ideas to others (Mauffette-Leenders, Erskine, & Leenders, 1997). Therefore, cases promote the ability to discern the essential elements in a situation, to analyse and interpret data, and to use those insights to inform action (Pearce, 2002). Students are thereby offered the opportunity to improve both their judgment and critical thinking skills by (a) participating in the analysis and solution of relevant problems, (b) seeing how theory applies in practice, and (c) learning by doing and teaching others (Merseth, 1999).

The instructional purpose of CBL was used for the first time in the University of Harvard in the beginning of the 20th century. As the main objective, law students had to find the solution to a specific story and defend it. This first experience was known as 'The case system'. During the first part of that century, this method was being developed and becoming definitive. Subsequently, it was being implemented in different educational fields.

CBL is now used around the world as a primary means for teaching in a wide variety of disciplines (Erskine, Leenders, & Mauffette-Leenders, 1998). For example, the case method has found successful application in such areas as accounting, nursing, psychology, physical education, teacher education, physical science, library management, public administration, and others (Pearce, 2002). This trend reflects the idea that students can approximate real-world experience without risking real harm if their strategies are ill-designed or if their interventions are poorly crafted (Harrington, Quinn-Leering, & Hodson, 1996).

Cases can be introduced in a wide variety of formats. They also can be very different among them –for example, cases focussed on the study of descriptions, on decision-making for problem solving, on situation-simulation, etc. A good case should accomplish the following requirements: (1) show content or significant issue of the education, (2) include relevant elements or factors of the content, (3) present the complexity and multidimensionality of the situation, (4) highlight the principles and assumptions of the discipline that underlie the case, (5) provide information to support the case analyses, and (6) promote the generalization of possible solutions and alternatives to the problem or case presented (Coll, Mauri, & Onrubia, 2008).

According to Shulman (2002), a case discussion typically lasts at least an hour and has the following four parts: (1) *What's Going On* (identifying the important facts of the case), (2) *Analysis* (raising questions and issues, analysing challenges from multiple perspectives, evaluating solutions proposed in the case), (3) *Action* (proposing alternate solutions, considering advantages and limitations of each, and the short- and long-term consequences of each), (4) *What Is This a Case Of?* (creating generalizable topics, principles). However, there are a variety of ways to implement the case method of teaching. In CBL, the teacher is central to the process: leading the discussion by asking questions; calling for volunteers; probing, recording and facilitating student comments; supplying data, theory, or insight that may enhance the thinking and learning in class (Pearce, 2002).

Technology has been updating certain practices of CBL, which has been called online case-based learning. For instance, eCASE (Context Awareness Supporting Environment) has been designed as an online CBL environment in the framework of the European team *Kaleidoscope*. In this proposal, four fundamental entities are crucial: the case, the scenario, the path and the scripts, in order to support the analyses and discussions of the participants (Demetriadis, Papadopoulos, Stamelos, & Fischer, 2008).

3.1.3. Problem-based learning

Problem-based learning (PBL) can be understood as a learning method or, in some cases, as a broader approach to learning (Schmidt, 1983) that supports social constructivist (Vygotsky, 1978), experiential learning theories (Dewey, 1953; Kilpatrick, 1918, 1925; Kolb, 1984), and student-centred learning (Rogers, 1980). In PBL, students learn about a subject in the context of complex, multifaceted, and realistic problems.

The objectives of PBL include helping students develop flexible knowledge, effective problem-solving skills, self-directed learning skills, effective collaboration skills, and intrinsic motivation (Hmelo-Silver, 2004). Taking part in a 'tutorial group', students identify what they already know, what they need to know, and how and where to access new information that may lead to the resolution of the problem. The task of the tutor –or instructor, or teacher– consists in facilitating learning by providing appropriate scaffolding and supporting the process, modelling the process, and monitoring the quality of learning and intervening when necessary (Schmidt, Rotgans, & Yew, 2011). The tutor must build student confidence to take on the problem, encourage the student as well as expand their understanding and learning process (Barret, 2011).

PBL had its first application and development in the medical school program at McMaster University in Hamilton, Ontario (Canada) in the late 1960's by Howard Barrows and his colleagues (Barrows, 1996; Neville, 2009). The McMaster University Faculty of Health Sciences established a new medical school with an innovative educational approach to be used throughout its entire three-year curriculum, which was developed in order to stimulate, assist the learners in seeing the relevance of learning to future roles, maintain a higher level of motivation towards learning, and show the learners the importance of responsible, professional attitudes (Barrows, 1996).

Afterwards, the use of PBL has expanded into other areas related with other health sciences, math, law, education, economics, business, social studies, and engineering (Barrows, 1996; Gasser, 2011). The application of PBL, like other student-centred pedagogies, has been motivated by the recognition of the failures of traditional instruction (Boyer Commission, 1998) and the emergence of deeper understandings of how people learn (Bransford, Brown, & Cocking, 2000; National Research Council, 2000). As opposed to traditional instruction, PBL actively engages students in constructing knowledge. PBL includes problems that have more than one solution; therefore they can be solved in many different ways (Cotič & Zuljan, 2009). According to Schmidt et al. (2011), a good problem in PBL should be authentic, be adapted to the students' level of prior knowledge, engage students in discussion, lead to the identification of appropriate learning issues, stimulate self-directed learning, and be interesting.

Following Barrows (1996), the main features of PBL are the following six: (1) PBL consists of student-centred learning, (2) learning occurs in small groups, (3) teachers (known as tutors in PBL) act as facilitators or guides, (4) a problem forms the basis for organized focus and stimulus for learning, (5) problems stimulate the development and use of problem-solving skills, and (6) new knowledge is obtained through means of self-directed learning.

In this learning method, students are encouraged to take responsibility for their group and organize and direct the learning process with support from a tutor or instructor. Research has pointed out that PBL can be used to enhance content knowledge at the same time as other skills –such as communication, problem-solving, critical thinking, collaboration, and self-directed learning skills– are fostered during the learning process (Barrett, 2010; Wells, Warelow, & Jackson, 2009).

Another critical point of PBL is that students are positioned in a simulated real world working (Cotič & Zuljan, 2009) and professional context which involves policy, process, and ethical problems that will need to be understood and resolved to some outcome. In PBL, students learn to negotiate the complex sociological nature of the problem and how competing resolutions may inform decision-making. This is accomplished by working through a combination of learning strategies to discover the nature of a problem, understanding the constraints and options to its resolution, defining the input variables, and understanding the viewpoints involved. The process of PBL has been described as being seven main steps (Schultz & Christensen, 2004; Schmidt, 1983):

<u>Opening session:</u>

- **Examination of the case**. The group gets familiar with the case material (i.e., reading the text where the case containing the problem is presented).
- **Identification of the problem**. An initial title for the case is specified by students.
- **Brainstorming**. The students present their association and ideas about the problem to find out what is already known and how does the case relate to their previous knowledge. The ideas are said aloud and written on self-stick notes, which are organized on a white board.
- **Sketching of an explanatory model**. An initial version of the explanation for the problem is constructed and the most important concepts and their relations are identified.
- **Establishing the learning goals**. The parts of an explanatory model that are mysterious, fuzzy, or simply unknown are identified and the central ones are chosen as learning goals for the group.

<u>Study period:</u>

- **Independent studying**. Each learner studies independently to accomplish all learning goals. This phase includes information gathering and usually a substantial amount of reading.

<u>Closing session:</u>

7. **Discussion about learned materials**. Equipped with newly acquired knowledge, the group reconvenes to discuss the problem. The discussion includes explanation of central concepts and mechanisms, analysis of the material, and evaluation of its validity and importance.

Recently, technology has been included in PBL methodology. As an example, the BioWorld has been designed by Lajoie et al. (2001). BioWorld is a computer learning environment designed for high school biology students. BioWorld complements the biology curriculum by providing a hospital simulation, in which students can apply what they have learned about body systems to problems where they can reason about diseases. Students work collaboratively (Web-supported) at collecting evidence to confirm or refute their hypotheses as they attempt to solve BioWorld problems. The use of PBL as a basis of a computer-supported collaborative learning has materialized in wiki-based environments (i.e., Kennedy & Rosdahl, 2008; Pifarré, Argelagós, & Guijosa, 2010), blog-based environments (i.e., Chhabra & Sharma, 2011; Vendrell, Pifarré, Sanuy, Argelagós, & Guijosa, 2010; Zorco, 2007), and other Web 2.0 tools (i.e., Dohn, 2009).

3.1.4. Project-based learning

Project-based learning, or PBL –in this dissertation we will call it PjBL to differentiate it from problem-based learning– is an instructional method based on social constructivism (Vygotsky, 1978), situated learning (Boaler, 1999), inquiry-based learning, and especially the project method (Kilpatrick, 1918). Kilpatrick developed the project method for early childhood education, which was a form of Progressive Education organized curriculum and classroom activities around a subject's central theme. In that method, the role of a teacher should be that of a "guide" as opposed to an authoritarian figure. Kilpatrick believed that children should direct their own learning according to their interests and should be allowed to explore their environment, experiencing their learning through the natural senses (Gutek, 2009).

PjBL provides students with complex tasks based on challenging questions or problems that involve the students' problem solving, decision making, investigative skills, and reflection that includes teacher facilitation, but not direction. This method is focused on questions that drive students to encounter the central concepts and principles of a subject hands-on. Students form their own research of a guiding question; this question allows students to develop valuable investigation skills. Through PjBL, students learn from these experiences, which take them into account and apply them to the world outside their classroom. This method promotes and practices new learning habits, stressing creative thinking skills by allowing students to discover that there are many ways to solve a problem.

PjBL was developed by the Buck Institute for Education in the late 1990s, in response to school reform efforts of that time (BIE, 2012). Nowadays, some teachers use PjBL extensively as their primary curriculum organizer and instructional method. Others use PjBL occasionally during a school year. Projects vary greatly in the depth of the questions explored, the clarity of the learning goals, the content and structure of the activity, and guidance from the teacher. The role of projects in the overall curriculum is also open to interpretation. Projects can guide the entire curriculum (more common in charter or other alternative schools) or simply comprise a few scattered hands-on activities. They might be multidisciplinary (more likely in elementary schools) or single-subject (commonly science and math). Some are whole class, others small group, and some individual. According to BIE (2012), PjBL can be effective at all grade levels and subjects, and in career/technical education, after school and alternative programs; PjBL should contain and frame the curriculum, which differs from the short "project" or activity added onto traditional instruction.

Evolving from medical and engineering schools, PjBL includes an emphasis on students constructing individualistic and shared understandings of important content and concepts as they explore the learning context (Schneider, Krajcik, Marx, & Soloway, 2002). Participating in and exploring the learning event often provides the impetus to engage content and develop skills, just as experts do in practice (Ward & Lee, 2002). With PjBL, students constantly pose and refine questions; they design and construct simple and/or complex investigations which require them to gather, analyse, and interpret data to report findings (Yetkiner, Anderoglu, & Capraro, 2008).

In a PjBL task, students are engaged in more idiosyncratic investigations, directing their own learning and making decisions about what they are going to do and how they will do it to achieve target goals. For this to occur, teachers need to create an environment and support a climate where students have the freedom to learn on their own, converse with each other, ask questions, and have autonomy to seek answers from a multitude of resources. Students who are engaged with finding a solution to a situation that is personally meaningful make the most of the experience, have increased motivation, and are willing to persist in the task, even when it is complicated, or when they experience certain difficulties or disappointments (Yetkiner et al., 2008).

The teacher is paramount in PjBL. The teacher's role implies allowing students to engage in developing personally and collaboratively negotiated meanings from the learning event (Kafai & Resnick, 1996). When teachers allow students more autonomy over what they learn, it improves motivation, and students assume more responsibility for their learning (Wolk, 1994). However, this does not mitigate the important need for the teacher to be actively engaged in the learning task as both a role model and an advisor.

In PjBL, students go through an extended process of inquiry in response to a complex question, problem, or challenge. Rigorous projects are carefully planned, managed, and assessed to help students learn key academic content, practice 21st century skills (such as collaboration, communication, problem-solving, and critical thinking), and create high-quality, authentic products and presentations.

According to BIE (2012), rigorous, meaningful and effective PjBL: (1) is intended to develop significant content, (2) requires critical thinking, problem-solving, collaboration, and various forms of communication, (3) requires inquiry as part of the process of learning and creating something new, (4) is organized around an open-ended driving question, (5) creates a need to know essential content and skills, (6) allows some degree of student voice and choice, (7) includes processes for revision and reflection, and (8) involves a public audience (Figure 5).

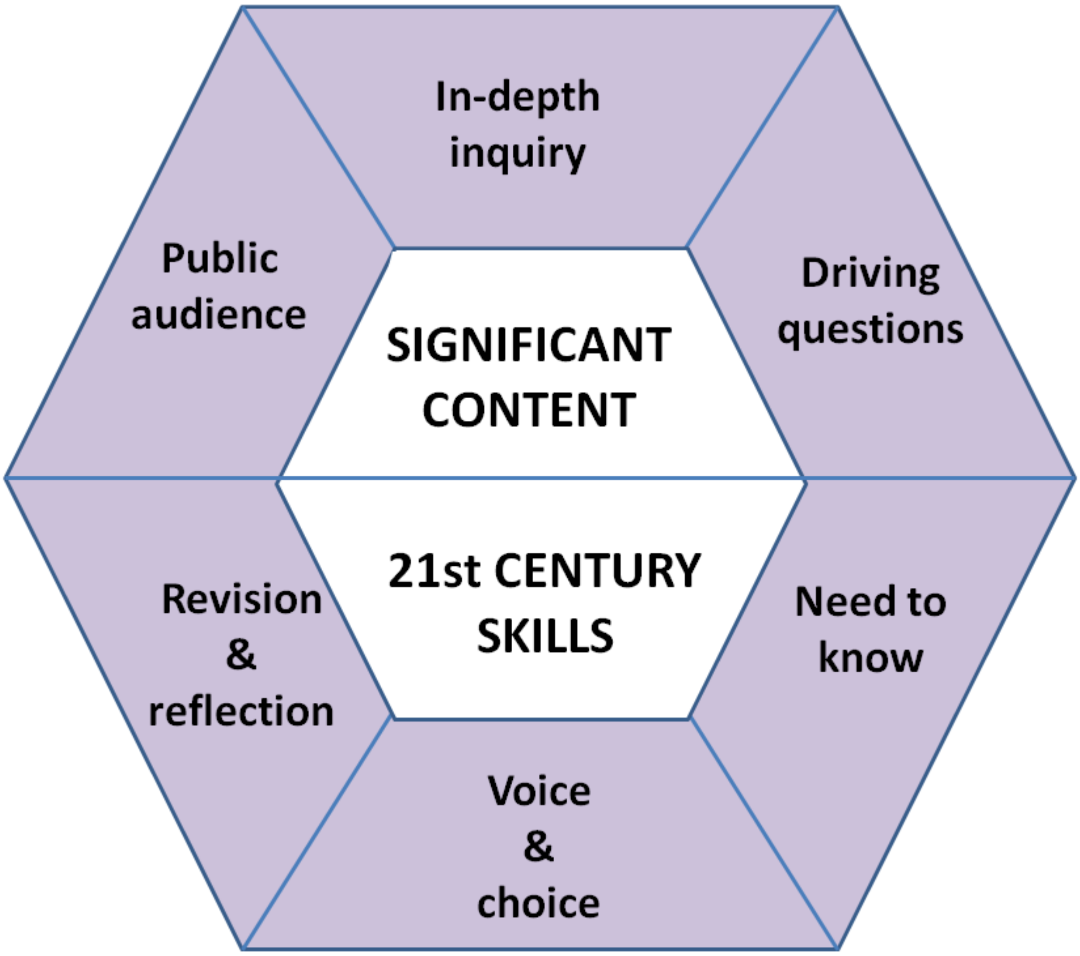

Figure 5. PjBL – Main features. Adapted from BIE (2012)

With PjBL, students gain a deeper understanding of the concepts and standards at the heart of a project. Projects also build vital workplace skills and lifelong habits of learning. Furthermore, projects can allow students to address community issues, explore careers, interact with adult mentors, use technology, and present their work to audiences beyond the classroom. *Assessment* in PjBL takes several forms, generally fitting into two broad classifications –formative and summative.

A PjBL environment can be created without the use of technology. However, the addition of technology in the classroom undoubtedly enhances the project based learning experience (Bie, 2012). Platforms and Web 2.0 tools have been used to provide online PjBL environments and support PjBL practices based on the Web.

3.1.5. Challenge-based learning

Challenge-based learning (CBL) –in this dissertation we will call it ChBL to differentiate it from case-based learning– is a learning method that has its roots in PBL and in experiential learning theories (Dewey, 1953; Kilpatrick, 1918; Kolb, 1984). This method focuses on increasing student engagement, especially for students most at risk of dropping out. By means of a collaborative learning experience, teachers and students work together to learn about different kinds of issues, propose solutions to real problems, and take action. Students are engaged to reflect on their learning and the impact of their actions, as well as to publish their solutions to a worldwide audience.

ChBL is a learning method for K-12 education, pioneered by education staff at Apple Inc very recently. The New Media Consortium published an in-depth analysis of a pilot study of ChBL in classroom practice in early 2009. This study, which involved 6 schools in the United States, 27 teachers, and 330 students in 17 disciplines, found the approach produced dramatically effective results, especially for the 9th grade students generally considered to be most at risk of dropping out.

ChBL includes these attributes: (1) multiple points of entry and varied and multiple possible solutions, (2) authentic connection with multiple disciplines, (3) focus on the development of 21st century skills, (4) 24/7 access to up-to-date technology tools and resources, allowing students to do the work, (5) use of Web 2.0 tools for organizing, collaborating, and sharing, (6) focus on universal challenges with local solutions, (7) requirement that students do something rather than just learn about something, and (8) documentation of the experience from challenge to solution (Johnson, Smith, Smythe, Troy, & Varon, 2009).

These attributes are intended to ensure that ChBL engages learners, provides them with valuable skills, spans the divide between formal and informal learning and embraces a student’s digital life (Johnson & Adams, 2011).

The framework of this method is presented in Figure 6.

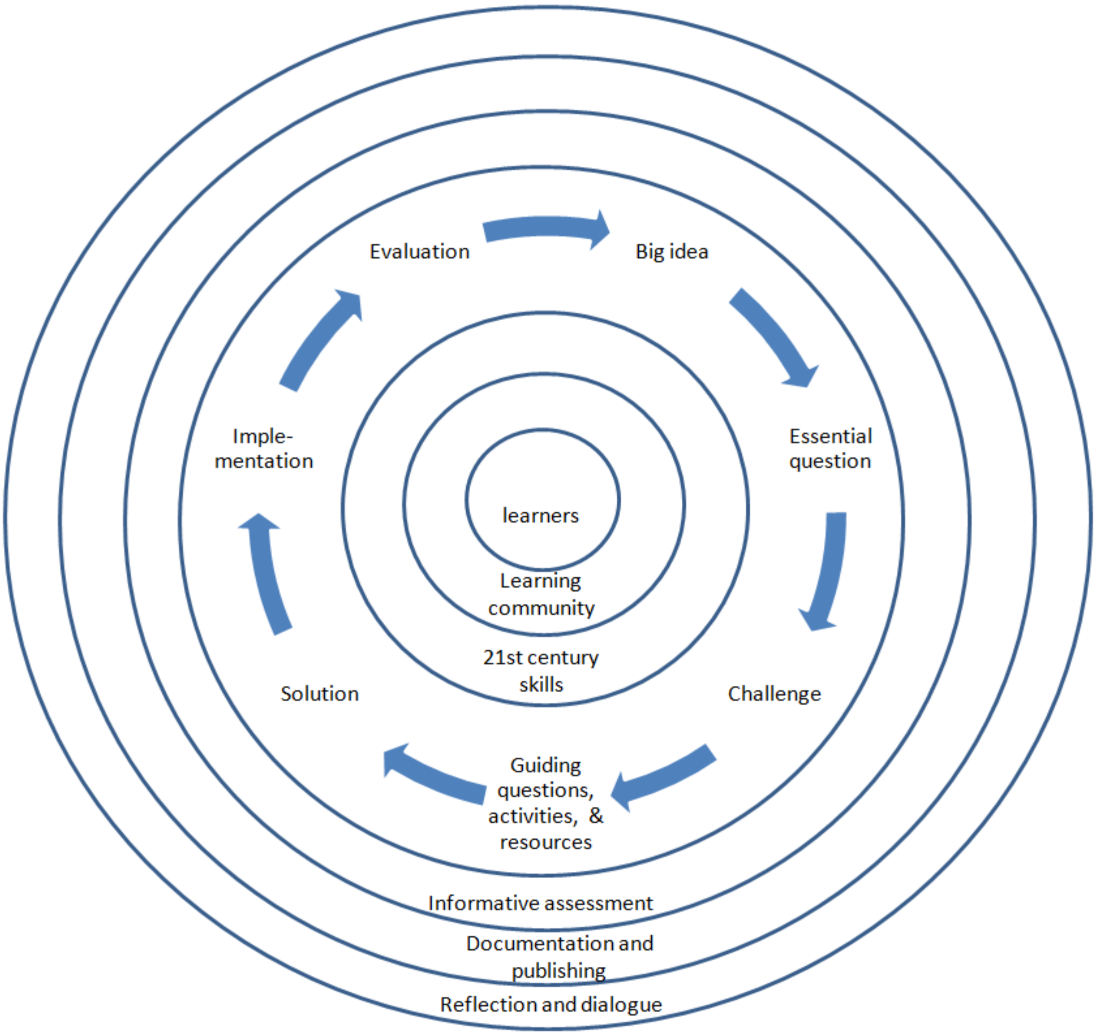

Figure 6. ChBL – Framework. Adapted from Jonhson et al. (2011).

This framework is carried out through several phases. Students are given enough space to be creative and self-directed and at the same time are provided with support, boundaries, and checkpoints to avoid frustration. The workflow can be structured and modified in a variety of ways. The following process is provided as a starting point but is not meant to be prescriptive[10].

1. **Collaborative Space** (How will the teams communicate? Where will resources be shared?). This workspace is (or should be) available to students 24/7, and it includes needed resources, access to activities, a calendar, and serve as a communication channel with the teacher and between the members of the team.

[10] www.challengebasedlearning.org

2. **Introduction** (Why is this idea important to the students? Why is this idea important to the community?). Once the "big idea" is selected, the first step is to develop with the class an overview of the big idea and the related "essential question". Then, the class identifies a suitable challenge.
3. **Team Formation** (What makes up a productive design team? How do we capitalize on everyone's skills?). It is important to consider roles and responsibilities during this team formation stage, as nowadays in real-world workplaces individuals with various skill sets typically work together in teams on specific projects or challenges.
4. **Assessment** (How will the process be assessed? How will the solution be assessed?). The teams, in collaboration with the teacher, discuss what they will use as an assessment of their success and adopt, adapt, or develop a project rubric to determine the success of their solution. Assessment should be conducted throughout the process and the product by both the students and the teachers.
5. **Guiding Questions** (What do we need to know in order to meet the challenge?). Once the teams are formed and organised, the students begin the process of identifying the questions that will guide their analysis of the challenge. These questions sketch what the students think they need to know to formulate a viable solution to the challenge. During the process, as information is gathered and concepts explored, questions will be answered, reframed, or new questions will be formulated.
6. **Guiding Activities** (What do we need to do to answer our guiding questions? What resources are needed?). The teams seek to find answers to the guiding questions by participating in a variety of learning activities, conducting research, experimentation, interviewing, and exploring various venues to assist in creating the best solution. The activities can be teacher directed or student directed, whole group, small group, or individual, depending on the topic and the need.
7. **Solution Development** (How do we meet the challenge? Is the solution justified?). After the students have identified possible solutions, they build them out, try them with small user groups, or present them to a focus group. This process allows the teams to refine their solution.
8. **Implement and Assess** (How can the solution be tested? Did the solution work?). This stage is to develop the implementation plan for the solution, put it

into action, and gauge the success of their implementation. The scope of implementation will vary greatly depending on time and resources.

9. **Document/Reflect** (What did we learn? What would we do differently?). Reflecting on the process allows developing the deepest learning, because learners think about one's own learning, their relationships with the content and between concepts, their interaction with other teammates, and their development of the solution. Documenting and reflecting on the process can be done by means of blogs, video, podcasts, digital storytelling, photographs, or other formats.
10. **Publish** (How do we share our results? What is the story behind the solution?). It is expected that students will create a short video about their solution, publish their work in a variety of locations, and submit it to the Challenge Based Learning Community.

3.1.6. Comparison among methods

The learning methods that we have described above have common points and differences among them. They are based on active and constructivist principles that give prominence to students and aim that they develop their own learning. The construction of their learning is carried out by conducting processes relative to research; starting from questions, problems, cases or real situations; using problem-solving strategies; applying different kind of skills, etc. However, they differ in origin and evolution, as well as in some characteristics in which each method is assumed and implemented. Table 2 intends to compare the key features between the methods. With this table as a starting point, we will compare these methods considering the following issues: origin, theoretical basis, problem-solving process, collaboration, guidance, hands-on, real-world connexion, final product, and use of the Web. This analysis will allow us to extract the key points that describe our methodological proposal (grey cells in the table indicate the key points considered in our proposal, which will be explained in Section 3 of this chapter).

Table 2. Comparative table about learning methods that involve Information-problem solving skills (grey cells indicate key features considered in our own instructional process)

	Inquiry-based Learning (IBL)	Case-based Learning (CBL)	Problem-based Learning (PBL)	Project-based Learning (PjBL)	Challenge-based Learning (ChBL)
Origin	Socrates (360 B.C.)	Fables, Parables. As a method: beginning of 20th century, Law faculty, University of Harvard	Barrows, 1960's, Medical school, McMaster University in Hamilton, Ontario	Kilpatrick (1918), early childhood education (USA) / Buck Institute of Education, 1990's	Apple Inc, 2008
Theoretical basis	Constructivism Experiential learning Piaget, Freire, Bruner	Constructivism Experiential learning IBL	Social constructivism Experiential learning Student-centred learning IBL	Project Method Social constructivism Situated learning IBL	PBL PjBL Experiential learning
Process	Starting with a question. Problem-solving	Making a decision on a case. Problem-solving	Starting with a problem. Problem-solving	Authentic research at school	Authentic research at a community of learners, beyond the school
Collaboration	Collaborative learning among peers (but not required)	Collaborative learning among peers (but not required)	Small tutorial group to solve the problem (discussion among peers)	Collaborative learning among peers	Collaborative learning among peers (also together with the teacher)
Guidance	Questions as scaffolds	From teacher	From teacher (tutor)	From teacher	From teacher, technology, experts,...
Hands-on	Possible, but not required	Usually not required	Possible, but not required	Required	Required
Real-world connexion	Possible, but not required	Required	Required	Required	Required
Final product	Required depending on the level of inquiry	Required depending on the kind of case presented and on the methodological format	Not required, normally	Required	Required
Use of the Web	Progressively adapted: Inquiry-Web Learning	Progressively adapted. i.e., "eCASE"	Progressively adapted. i.e., "BioWorld"	Progressively adapted. i.e., online PjBL environments	Since the beginning

As regards the **origin** of these methods, all of them come from different sources. The oldest methods are IBL (which was born with Socrates and his style of questioning to guide his disciples to learn and understand the real word) and CBL (which has its roots in traditional wise fables and parables, many centuries ago). However, IBL and CBL only became "methods of learning" at the beginning of the 20th century, and they were being progressively integrated into formal education.

It seems that IBL and CBL have created the basis for the development of other methods such as PBL, PjBL, and ChBL. In particular, IBL has been assumed as a style of guidance, which has been applied in education, apart from being considered as a method itself. Concerning CBL, the idea of considering a case, a problem, or a story as a starting point to learn contents is also present in PBL and PjBL.

In this line of reasoning, CBL, PBL and PjBL have been considered the same thing by some authors (i.e., Ward, 2002) and designed by the same tag ("PBL"). Therefore, PBL is referred to problem- and project- based learning. Furthermore, PBL and CBL have been indistinctively considered and they have included cases, problems, or projects to be analysed, solved or carried out.

Despite the relationship between the methods and its origins, all of them have been constituted as methods from different origins, as we mentioned above. CBL was implemented for the first time as a method of learning in the beginning of the 20th century at Harvard University (USA). Later, in the 1960s, PBL was applied as a method at the University of Hamilton (Canada). PjBL has been implemented since the "project method" (Kilpatrick) in the beginning of the 20th century in early childhood education (USA); however, later, in the 1990's, it was redefined by the Buck Institute of Education, in order to consider it as a learning method with more prescriptive characteristics and to be adapted to 21st century skills. Finally, ChBL has been born more recently in a clear basis of the PBL and PjBL, with the aim of integrating these previous methods with the idiosyncratic features of the technological and informational society of the 21st century.

Concerning the **theoretical basis** of these methods, every one departs from a constructive and active assumption of the learning, as was mentioned above. Some of them give more stress to social aspects (PBL, PjBL) or situated learning (PjBL). Others have represented the basis for other methods: for instance, CBL, PBL, PjBL and ChBL are based on IBL; and ChBL is based on PBL and PjBL.

As regards the **process** followed by each method, all of them start from a challenge that acquires the form of a question (IBL), a case (CBL), a problem (PBL), or a critical issue to be solved or investigated (PjBL and ChBL). More directly or more indirectly, these methods use a problem-solving pattern to carry out the process of learning. IBL and CBL are more flexible depending on the level of inquiry or the way of the consecution of the process. PBL, PjBL and ChBL assume more specifically their steps and requirements. PjBL and ChBL are more concerned with warranting an authentic research process at school and, additionally, to extend the research beyond the school, into a public audience (or into a community of learners and a worldwide audience, in the case of ChBL).

Table 3 shows the specific steps followed by each method to solve the problem, analyse the case, or carry out the project. The revision of the theoretical contributions of different authors presented in Chapter 2 of this dissertation showed similar phases in the models proposed by researchers who studied the problem-solving process. In that chapter, we concluded that the models shared the same main parts of the resolution of the problem: an ***initial phase*** to examine and identify the case, the problem or challenge, to determine specific questions or objectives to plan the research, action or study; an ***intermediate phase***, in which the experimentation, the action or the implementation take place in order to test the initial hypotheses or accomplish the objectives proposed; and in the end, a ***final phase***, devoted to draw conclusions, extract principles, discuss the learning, reflect about the process, and publish the work or findings.

The analyses of the methods of this section also points out the same line of problem-solving process, considering these three main phases. However, each method gives more or less stress to specific points. For instance, the first phase in IBL and CBL is concretized by two principal actions (*Orientation* and *Hypotheses generation* in IBL; *What's going on* and *Analysis of the objectives* in CBL) whereas PBL or ChBL is concretized by five or six specific actions, as can be appreciated in Table 3. The same happens in other phases.

Furthermore, another conclusion drawn from Chapter 2 was the importance of ***regulation activities*** accompanying the problem-solving process. The methods of learning and teaching that have been analysed in this section, also give different emphasis to regulation. In this way, IBL specifies the necessity of orientating, planning, monitoring, and evaluating during the inquiry process. PjBL and ChBL prescribe evaluation and reflection at the end of the process. Nonetheless, it is worth noticing that, i.e., PBL usually includes an assessment of the process or product by both tutor and students, and this fact allows concluding that regulation is also present during the PBL process, despite it not being directly specified in the steps of the problem-solving process (e.g. Argelagós, 2006; Wells et al., 2009).

Table 3. Steps in the problem-solving process of each method (in bold, regulation activities)

	IBL	CBL	PBL	PjBL	ChBL
Initial phase	**Orientation** Hypotheses generation	What's going on Analysis	Examination of the case Identification of the problem Brainstorming Sketching of an explanatory model Establishing the learning goals	In-depth inquiry Driving questions Need to know	Big idea Essential question Challenge Guiding questions Activities & resources Solution
Interm. phase	Experimentation	Action	Independent studying	Voice & Choice	Implementation
Final phase	Drawing conclusions **Evaluation** **Planning** **Monitoring**	What is the case of	Discussion about learned materials	**Revision & Reflection** Public audience	**Evaluation** **Reflection** & documentation Publication

As regards the kind of **collaboration** assumed, it also differs from method to method. In IBL and in CBL collaboration is advised but not required due to the fact that it is possible to assume the learning process in an individual way in these methods. The way of solving the problem in the PBL method has the particularity of the tutorial group in which students follow specific steps to discuss among them and to individually study. PjBL and ChBL require a collaborative team to work, with peers and with peers and teacher, respectively.

Concerning the **guidance** provided to the students on their process of learning and problem solving, this is given in a similar way and also in a different way among the methods. On the one hand, in IBL and in the methods based on inquiry (CBL, PBL, PjBL and ChBL), the set of questions provided by the teacher assume the role of help and guidance to students. For example, in the PBL tutorial group in which the problem-solving process takes place, the tutor (teacher) has an important role to guide students by means of questions and not by statements or conclusions, allowing students to discover these by themselves. On the other hand, ChBL is the unique method that, from the beginning, is supported by technology and other experts, apart from the teacher. The other methods can do the same, but not as a requirement. The support of the technology, however, is increasing in the practice of these methods, by means of technological scaffolds, which are widely embedded in Inquiry-Web Learning environments and in online versions of CBL, PBL and PjBL methods.

Another feature is **hands-on**. This refers to the involvement of active participation from students, as a real practice to solve the problem presented, or to accomplish the project or the research planed during the process. The methods we are analysing differ on the requirement of hands-on: IBL and PBL have the possibility of hands-on, but it is not required to carry out the normal process of solving problems; in particular, in IBL, it will depend on the level of inquiry used; in CBL, hands-on is usual, but also not required; finally, PjBL and ChBL require hands-on during their learning process, as students have to plan research or implement a solution, collect data, analyse and assess it, etc.

Regarding the **real-world connection**, all the methods defend the necessity of keeping a narrow relation between theory and practice; it means that the contents addressed by the learners should have a high connection with the real world. This produces motivation in students and makes sense for the learning. However, IBL not always assures this real-world connection, since it depends on the level of inquiry in which students are involved. For instance, the lowest level of inquiry (confirmation level) can be used to train specific skills of students and not to perform all the inquiry process; in that case, it could be possible that real-world connection is not completely reflected.

The same happens with the **final product** required. In IBL, this will also depend on the level of inquiry. In CBL, as well, it will be influenced by the kind of case or the kind of instructional design to solve or analyse the case. In PBL, a final product usually is not required, whereas it is always asked in PjBL and ChBL. In addition, ChBL usually needs to report the finding to a worldwide audience by means of a report, video, blog post, or others. Nevertheless, the lack of requirement for a specific material final product does not mean that a learning process or a problem-solving process has not been produced. A final product refers to a material artefact that reflects the solution of the problem or the process executed by students, but a solution of a problem can also be appreciated by the discussion during the last step of the tutorial group in PBL, for example. Therefore, an assessment of the product and process will be carried out depending on the final product required or the kind of solution demanded.

Finally, the **use of the Web** in each method has to do with the presence of the general Web use in the moment of the rise of the method. Among these methods, only the ChBL has been born in the middle of (and, maybe, due to) an Information Society. For this reason, technologies and all of its affordances, including Web 2.0 tools, have been integrated in the design of ChBL. The other methods, which evolved before the explosion of technology, have been progressively adapting technologies into their methodological approaches and their practices, due to the multiplication of the affordances and the possibilities that technologies permit: to tackle more and diverse information, participate, communicate, discuss, etc. Thus, online versions and computer-supported collaborative learning environments have been developed to hold and facilitate the integration of technological tools into these methods. This integration has also resulted in the need of scaffolding these kinds of new interactions between the learners, in order to promote better learning and problem-solving processes.

* * *

The methods of learning and teaching described and analysed in this section share several points and also differ in other ones. Based on active and constructivist theories, they allow students to develop their own learning and be protagonists in carrying out a problem-solving process. In those methods, the process to solve a problem starts from questions, cases, or real situations, and follows the main parts that the problem-solving models revised in Chapter 2 also suggested. Furthermore, the methods analysed in this section differ in giving emphasis in some of the phases of the problem-solving process, and in the way in which they predict the regulation activities.

Those methods also have differences in their origin and evolution, as well as in some characteristics in which each method is assumed and implemented.

The comparison and the analyses of the learning and teaching methods presented in this section means a strong starting point to describe our methodological proposal, which aims to help students to develop cognitive processes and skills to solve problems with the use of the digital information in the Internet, while learning curricular contents at school in their everyday classrooms. Next, we highlight the key points extracted from the analyses of the learning methods in order to introduce our methodological proposal, which will be expanded in Section 3 of this chapter.

3.1.7. Key points considered in our methodological proposal

In Table 2, we highlighted the key points that we consider in our methodological proposal. By highlighting those points we can easily understand where each key point comes from, or what each one is based on. As with all the methods analysed, our proposal has an active and constructivist **theoretical basis**, and gives a prominence to students to learn and carry out their problem-solving process. Inspired in **Inquiry-Web Learning**, a set of Web-based tasks were developed in four academic subjects through the scholar curriculum. In each Web-based task, the problem-solving process is **guided** by the **teacher** and **technological scaffolds**, and is performed in **collaboration with peers**. Technological scaffolds have been embedded in each Web-based task in order to help students to accomplish the main phases of the IPS process and also to **regulate** it. Those tasks always depart from a real or realistic situation and assure the **real-world connection**. Each Web-based task asks for a **final product** to be constructed by the students through the problem-solving process, and these products vary on the format from task to task: a report, a slide presentation, a screenplay, an email, etc. The **use of the Web** is omnipresent during the whole problem-solving process. A more detailed description of our methodological proposal is provided in Section 3 of this chapter.

Before presenting in detail our methodological proposal, we will revise research studies that have been conducted to support IPS skills and to analyse their impact on participants. Some of these studies show instructional support addressed to children, to teenagers, and to adults. In addition, some studies show specific IPS instruction embedded in the scholar curriculum; other studies analyse IPS instruction carried out without a connection with the curriculum followed by the students at school. Our main interest relies in research on embedded instructional support in IPS conducted in Secondary Education.

2. Research on Instruction in information-problem solving

In order to design the main educational guidelines of embedded instruction of IPS skills in Secondary Education, our study starts, on the one hand, from the analyses of the learning and teaching methods involving IPS processes that we presented in the previous section and, on the other hand, from previous studies on embedded instruction conducted in secondary classrooms. The contributions and limitations of these studies are presented below together with our plan on how to overcome the latter.

Many effective embedded instruction research studies have been conducted in Primary Education (i.e., Hoffman, Wu, Krajcik, & Soloway, 2003; Kuiper et al., 2008; Pritchard & Cartwright, 2004; Spink, Danby, Mallan, & Butler, 2010; de Vries, et al., 2008; Wang, Ke, Wu, & Hsu, 2011). However, embedded instruction studies in Secondary Education are scarce (i.e., Badilla-Quintana et al., 2011; Britt & Aglinskas, 2002; Raes, Schellens, de Wever, & Vanderhoven, 2011; Walraven et al., 2010). Most IPS instruction in Secondary Education is implemented as separate courses, loosely connected to the curricular contents (i.e., Colaric, 2003; Feddes, Vermetten, Brand-Gruwel, & Wopereis, 2003; Gerjets & Hellenthal-Schorr, 2008; Lazonder, 2001; Sanchez, Wiley, & Goldman, 2006; Stadtler & Bromme, 2008; Walton & Helpworth, 2011). Table 4 shows a review summary of IPS instruction.

Table 4. Review summary of IPS instruction (grey cells indicate research on embedded instruction in Secondary Education)

Research study	**Level of education**	**Kind of instruction (kind of learning method)**	**Object analysed**	**Data analysed / techniques**	**Methodological research approach**	**Effect**
Badilla-Quintana et al., 2011	Primary and Secondary Education	Embedded (not instruction, but exposition)	Computing tools knowledge and management Digital literacy	Student questionnaires Task-resolution logfiles Student answers	Quantitative	Partially positive
Britt et al., 2002	Secondary and Higher Education	Embedded	Sourcing and corroborating while reading history texts	Student note sheets Student essays Student answers	Qualitative Quantitative	Positive
Colaric, 2003	Secondary Education	Not embedded	Using search engines Developing queries	Student questionnaires	Quantitative	Partially positive
De Vries et al., 2008	Primary Education	Embedded	Reflective Web searching	Observations Interviews Group products	Qualitative	Partially positive
Feddes et al., 2003	Higher Education	Not embedded	Strategic knowledge about IPS and regulation	Student self-report questionnaires Student self-report descriptions In-depth interviews	Qualitative	Partially positive
Gerjets & Hellenthal-Schorr, 2008	Secondary Education	Not embedded	Declarative and procedural knowledge on Web searching	Student questionnaires Student task resolution	Quantitative	Positive
Hoffman et al., 2003	Primary Education	Embedded	Content understanding Search and assess strategies Quality of online resources	Task-resolution logfiles Interviews Videos	Qualitative	Positive

Kuiper et al., 2008	Primary Education	Embedded	Web searching, reading and evaluating skills in content knowledge domain	Videotaped and written lesson observations Interviews with teachers and students Teacher diaries Student questionnaires Student assignments	Multiple case study design Qualitative Quantitative	Partially positive
Lazonder, 2001	Secondary Education	Not embedded	Self-regulation in Web searching	Student questionnaires Task-resolution logfiles	Quantitative Qualitative	Partially positive
Pritchard et al., 2004	Primary Education	Embedded	Engagement Knowledge transformation (end products that mentions the process)	Student essays	Qualitative Class-case study	Partially positive
Raes et al., 2011	Secondary Education	Embedded (Inquiry-Web Learning)	Domain-specific knowledge Metacognitive awareness	Student answers Student self-report inventories	Qualitative Quantitative	Positive
Sanchez et al., 2006	Higher Education	Not embedded	Evaluating the source and quality of the information	Student assignments Student essays	Quantitative	Positive
Spink et al., 2010	Primary Education	Embedded	Web search behaviour	Video and audio while Web searching	Qualitative	Positive
Stadtler & Bromme, 2008	Higher Education	Not embedded	Metacognition on Web search	Pre-selected websites assignments Multiple-choice tests Essays	Qualitative Quantitative	Partially positive
Walraven et al., 2010	Secondary Education	Embedded	Evaluating results, information and source while Web searching	Student evaluation of hit list Student evaluation of Websites Student think-aloud protocols Field notes	Quantitative Qualitative	Positive

Walton & Helworth, 2011	Higher Education	Not embedded	Evaluation of information	Interviews Focus groups Online discussions Written assignments	Qualitative	Positive
Wang et al., 2011	Primary Education	Embedded	Learning motivation Information literacy	Observations in class Self-reported questionnaires Interviews with selected students Student postings on the blog Student assignments	Qualitative	Partially positive

In order to extract the main contributions and limitations presented by the studies in which our interest is focussed, in the following paragraphs we will analyse the research studies on embedded instruction in secondary classrooms. This analysis will allow us to draw the main guidelines to be considered in our methodological and instructional proposal to foster IPS skills in secondary students at school.

Badilla-Quintana et al. (2011) carried out a Project in Elementary and Secondary Schools in Spain based on information and communication technologies (ICT), which consisted mainly in providing technological equipment to the participating centres such as digital interactive whiteboards, audiovisual systems, scanners, computers, laptops, printers, and a series of connectivity points to the Internet, as well as other didactic resources. Although the project reported improvements in the participants' knowledge and control of computers and operating systems, and in their information management skills through the Internet (finding, assessing and using the information), the lack of systematic instruction on IPS skills did not help students to maximize their digital literacy. These results are similar to other reports that conclude that students do not always master more knowledge of basic ICT skills in spite of the increasing presence of ICT in the world and in schools (Kaminski, Switzer, & Gloeckner, 2009; Strømsø, Grottum, & Lycke, 2004).

The study of Britt & Aglinskas (2002) analysed the impact of embedded instruction –scanning and processing information while searching– on teenagers and university students. The method of learning was based in a computer-based tutorial and practice environment for teaching students to source and corroborate while reading history texts, but it was not based on any learning and teaching method analysed in the previous section of this chapter. The researchers of this study concluded that the results were effective in Web-searching processes. However, the instruction received only focused on the sources and the information rather than on other constituent skills considered in IPS (Brand-Gruwel et al., 2005).

Another interesting embedded intervention in secondary school classrooms was carried out by Raes et al. (2011). This was a large-scale intervention with the purpose of improving domain-specific knowledge and metacognitive awareness of the students' IPS processes by means of scaffolds. The method used to foster IPS skills was Inquiry-Web Learning. The study measured the IPS skills by means of self-reporting after the IPS task performance. The findings showed an overall improvement of the students' performance. However, the authors also reported that one of the limitations of their study was the lack of analysing deeply the learning processes during the task performance, which could have given more insight into the IPS cognitive processes performed and could have shed more accurate conclusions on the effect of scaffolding during the learning process.

Other research studies have faced the issue of how to help students to transfer IPS skills to other contexts. Walraven et al. (2010) designed and evaluated two educational programs to foster IPS skills in secondary classrooms in order to test two transfer theories. The first program was based on the theory that transfer is enhanced by paying attention to the steps that have to be taken in an IPS process; and the second program was based on the theory that transfer of cognitive processes is fostered through the development of a knowledge structure. Those programs did not follow any of the methods described in the previous sections, but consisted in a learning process directed by the teacher. This study reveals the need of more research that guarantees the *transfer* of IPS processes to other subjects or areas. Other studies support this conclusion (i.e., Brand-Gruwel et al., 2010; Ten Dam & Volman, 2004).

In addition, most IPS studies are short-term studies and the authors admitted that further *long-term* studies should be developed in order to see whether the positive effects of the instructional process were maintained over time (Braten, Strømsø, & Salmerón, 2011; Walton & Helworth, 2011).

Furthermore, Wopereis et al. (2008) argued the need to study the design of effective IPS instruction. In their study, these authors claimed that effective IPS instruction should take into account the following two instructional principles: (a) IPS instruction should be embedded in *authentic learning tasks* in which learners aim the integration of knowledge, skills, and attitudes necessary for effective 'overall' task performance, and (b) the instruction should design effective *scaffolds* to guide the development of the IPS process; in this line, worksheets accompanied with driving questions, which guide and direct students during the problem-solving process, are emphasized as effective in IPS instruction.

In light of the conclusions from the learning methods that involve IPS processes, and from previous studies on IPS instruction on Secondary Education, our methodological and instructional proposal takes into account embedded, structured and supported variables. Our proposal integrates these three variables in the design of the instruction implemented and evaluated in our research work. It can briefly be described as: (1) *embedded* in a meaningful and real context (classroom) spanning two academic years with a view to developing IPS cognitive processes and task performance, and learning from the Web, (2) *structured* by designing Web-based tasks which follow the Inquiry-Web Learning and, in particular, the WebQuest structure (Dodge, 1995), and (3) *supported* by providing scaffolds in the several cognitive processes needed to tackle information-problems.

In the following section, we present our proposal as an intervention and describe the main characteristics of our IPS methodological and instructional process.

3. Our intervention: characteristics of the information-problem solving instructional process

Considering, on the one hand, the information-problem solving contributions reviewed in Chapter 2 and, on the other hand, the learning methods that involve problem-solving process as well as the instructional processes carried out in IPS at school (reviewed in the previous sections of this chapter), in this section we will present the characteristics of our intervention to enhance cognitive processes involved in IPS.

The IPS Web-based tasks of the instructional process were designed by teachers and researchers, and were devoted not only to training IPS processes, but also to learn curricular contents. The activities belonged to the following areas: technology, maths, science and social science[11]. Each task consisted in an authentic learning task within approximately four sessions of 60 min each. The experimental condition involved students participated in nine Web-based tasks (36 hours in total) during the first year of the instructional process, as well as six Web-based tasks (24 hours in total) during the second year. Thus, they received as many as 60 hours of instructional process.

The students worked in pairs during the instructional process to solve the IPS tasks collaboratively. Walraven et al. (2008) reported and analysed several studies dealing with instructional support in IPS, and pointed out that the collaborative nature of the instruction was one of the key instructional variables that contributes to improving certain sub-skills, such as 'formulating questions' and 'activating prior knowledge'. These are both critical skills included in the constituent skill 'defining the problem'. Collaboration encourages students to articulate their thoughts, and these verbalizations of one's own thoughts might have a positive impact on problem-solving (Teasley,

[11] For samples of those activities, the reader can click on the following link: http://contic.udl.cat/en/resources/secondary

1995). In addition, peer interaction urges users to negotiate the suitability of search strategies and decisions, and to give the opportunity for users to critically observe each other's actions, which may facilitate early detection and correction of potential mistakes (Lazonder, 2005; Okada & Simon, 1997).

The key instructional principles that guided the Web-based instructional process were the following three: (i) *embedding* the IPS skills in authentic curricular tasks, (ii) *structuring* the students' problem solving and (iii) *supporting* the students' problem resolution with specific scaffolds. In the following paragraphs we will expound the characteristics of the intervention (Figure 7).

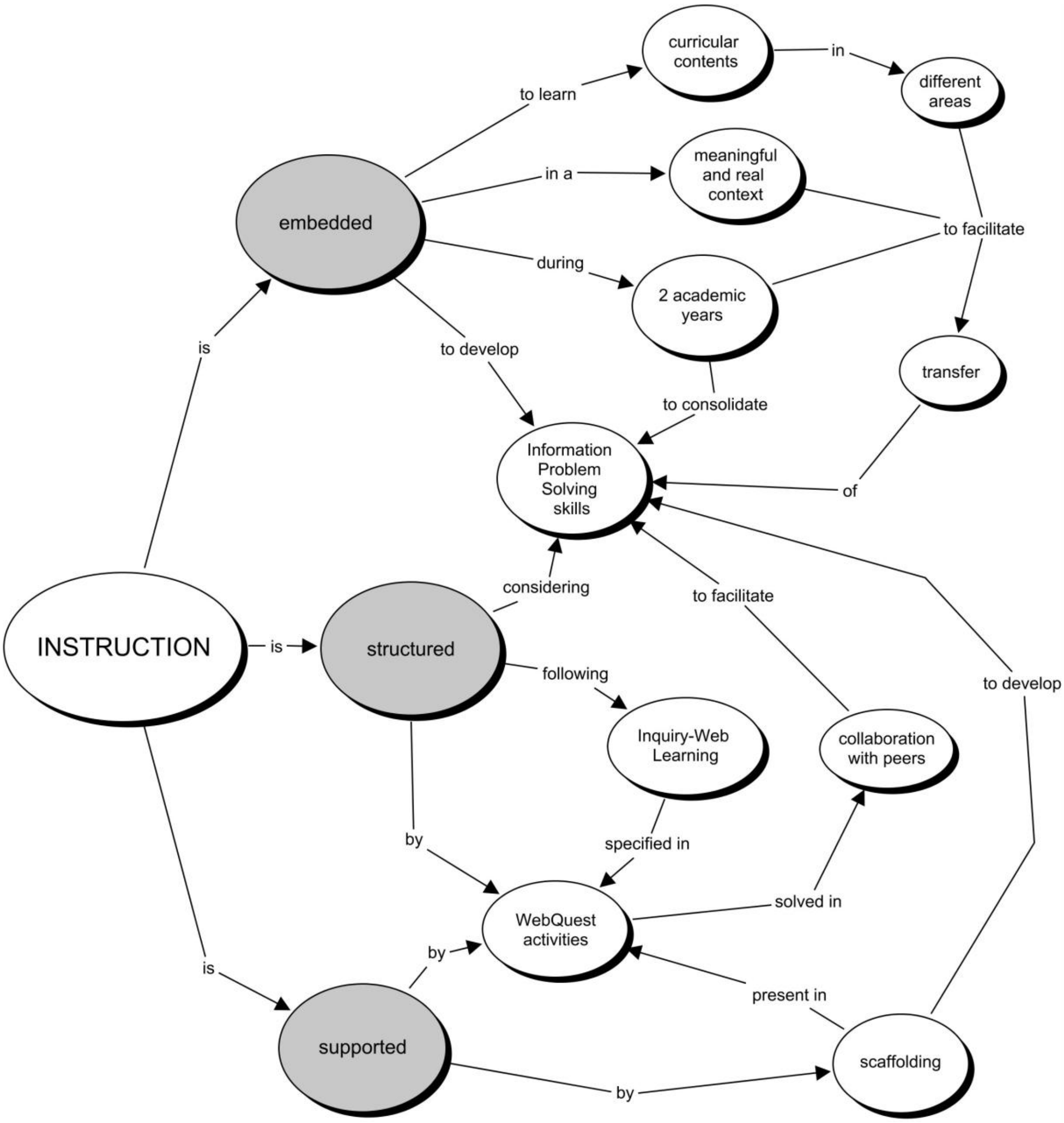

Figure 7. Concept map of the characteristics of our intervention

(i) One of the key instructional principles that guided the instructional process was the ***embedding*** of the instruction to construct curricular knowledge in a real context. The design of our instructional process enhanced meaningful knowledge construction (de Vries et al., 2008), promoted transferability of IPS to solving problems in other contexts (Brand-Gruwel et al., 2009), and was due within a period of time long enough to acquire and consolidate the Web skills trained. In view of these important pedagogical considerations of IPS instruction, our project was designed to practise contents of four different curricular disciplines and was implemented during two academic years.

(ii) The second key instructional principle that guided the instructional process was ***structuring*** the students' problem solving by using a WebQuest approach (Dodge, 1995), which is based on Inquiry-Web Learning, as we analysed in previous sections of this chapter. This approach consists in giving students an authentic problem to solve using Web resources. We chose a WebQuest methodology because it fit into the main IPS instructional principles extracted from our analysis of the learning methods and from the research studies in IPS instruction. Below, we will point out briefly the four pedagogical principles for using a WebQuest approach in our study:

(a) WebQuest methodology is grounded on the Inquiry-Web Learning method. This methodology focuses on a real learning problem which students need to solve by integrating knowledge, skills and attitudes, and using Web resources.

(b) Students have to search the Web for a well-defined objective. This principle sets up a good scenario to embed explicit IPS instruction in order to improve the Web-searching, Web-selecting information, and organization of the Web information.

(c) A WebQuest provides a well-defined structure for the learning processes (Zheng, Perez, Williamson, & Flygare, 2008). A well-designed WebQuest usually contains six stages: (1) introduction, (2) task, (3) information sources, (4) description of the process, (5) performance evaluation, and (6) conclusion. This structure fits the way problems are solved, as was analysed in Chapter 2 and in the previous section of this Chapter 3. Therefore, this structure allows us to introduce an IPS instruction in a natural way.

(d) WebQuest methodology promotes knowledge construction through the critical and creative use of Web resources. However, in a typical WebQuest the student is provided with a pre-selected list of websites, so that the use of the Web is quite limited (Caviglia & Ferraris, 2008). For this reason, all the Web-based tasks of our large project were enriched by a wide set of scaffolds to help students search, analyse, and organise Web information to successfully solve a digital problem (Pifarré, Sanuy, Vendrell, & Gòdia, 2008), further explained below.

(iii) Finally, the third key principle of our intervention was ***supporting*** with specific IPS scaffolds the students' problem solving. Supporting multiple students in a technology-enhanced classroom requires readjusting the notion of scaffolding (Luckin, Looi, Chen, Puntambekar, & Stanton-Fraser, 2011; Puntambekar & Kolodner, 2005). In this vein, scaffolding to support IPS processes is gaining recognition as an important instructional scaffolding method in computer-based learning environments (Bannert & Reimann, 2011) in complex classrooms (McNeill & Krajcik, 2009; Puntambekar & Kolodner, 2005; Tabak, 2004).

Scaffolds are defined as temporary supporting structures to promote student learning of complex problem-solving or reasoning (Bransford, Brown, & Cocking, 2000; McNeill & Krajcik, 2009). Within technology-enhanced learning environments, these can be displayed on screen at certain times in the learning process, because the students do not usually execute their IPS skills spontaneously (Bannert et al., 2011; Wood, 2009). Educational research provides evidence that it is possible to improve individual learning in a scaffold-based technology environment to activate their cognitive processes (Demetriadis et al., 2008).

In our methodological and instructional proposal, the Web-based tasks designed give guidance and specific scaffolds to learn skills in the main IPS constituent processes, namely (1) defining the information problem, (2) searching for information, (3) scanning and processing information, and (4) organizing and presenting information. We embedded these IPS skills in the WebQuest structure of all our activities. We presented these scaffolds by means of questions, worksheets (de Vries et al., 2008; Walraven et al., 2010; Wopereis et al., 2008), prompts (Morris et al., 2010; Stadtler & Bromme, 2008), pop-up messages, concept maps, simulations, and templates (Pifarré, 2009). Figure 8 presents an overview of the IPS scaffolds designed in the instructional process and some examples about how these scaffolds were displayed to the students. The IPS scaffolds were embedded in the whole learning task and gradually lost intensity as the instructional process progressed.

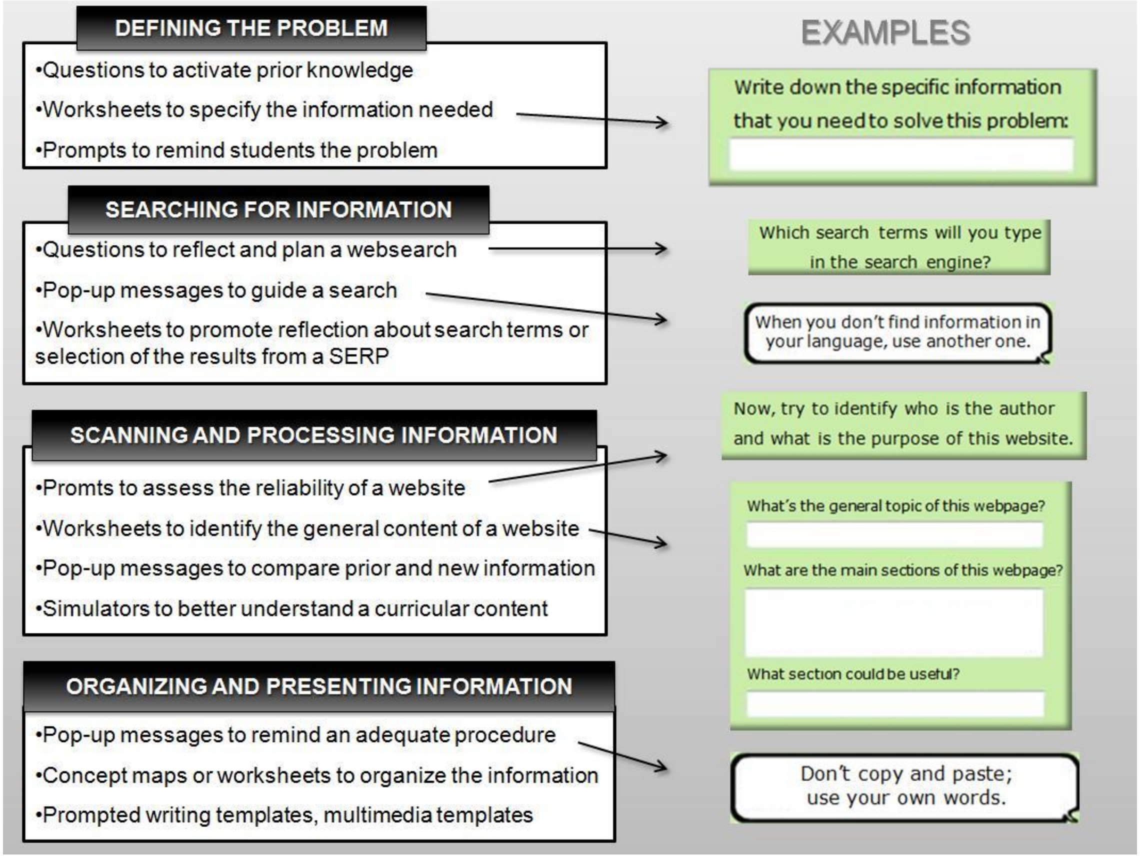

Figure 8. Scaffolds of each constituent skill during the instructional process (adapted from Pifarré et al, 2008)

Furthermore, specific scaffolds to enhance regulation were designed focused in the next four regulation activities: orientation, steering, monitoring, and testing. These scaffolds also were provided by means of questions, short messages, pieces of advice, etc.

Among regulative scaffolds provided to students we highlight the following seven: (a) scaffolds to activate prior knowledge and to help students determine what information is needed to successfully solve the IPS task, (b) scaffolds to promote students' reflection in selecting the most appropriate search engine, in thinking the search terms and in writing the appropriate Web information, (c) scaffolds to assist students in collecting and understanding the Web information, (d) scaffolds to encourage students to consider their own previous answers and their prior knowledge, as tools to construct new knowledge, (e) scaffolds to argue their answers and decisions,

f) scaffolds to revise and check their learning process, and (g) scaffolds to promote self-assessment in pairs about the IPS process –peer learning, level of engagement in solving the task, evaluation of content activity, level of difficulty, achievement, and own learning.

In addition, it has been suggested that scaffolds obey different purposes, for instance, Kim & Hannafin (2011) distinguished *procedural scaffolds* to guide students in addressing operational aspects of the learning environment; *conceptual scaffolds* to help students to identify essential knowledge gaps between what they already know and what they need to know, as well as students understanding the problem content; *metacognitive scaffolds* to assist learners in assessing their state of understanding, reflect on their thinking, and monitor their problem-solving processes; and *strategic scaffolds* to guide students to consider alternative approaches to addressing problems. Table 5 shows examples of scaffolds related with IPS skills, regulation activities, and the purpose of each scaffold.

Table 5. Examples of scaffolds provided for each IPS constituent skill

IPS constituent skill related	Examples of scaffolds	Regulation activities	Scaffolding purposes
Defining the problem	Workspace to answer questions about prior knowledge	Orientation	Conceptual
	Prompt to remember the problem to be solved	Orientation	Metacognitive
Searching for information	Pop-out message: "Don't copy and paste; use your own words"	Steering	Procedural
	Pop-out message: "When you don't find information in your language, you can use another one"	Steering	Procedural
	Question with an option list: "Which search engine will you use?"	Steering	Metacognitive
	Pop-out message: "When few results appear in your SERP, you can delete words from your search terms"	Monitoring	Procedural
	Question to reflect about the search terms used: "Write down what search terms you typed in the search engine to find this information"	Monitoring-Testing	Metacognitive
	Question to reflect about the URL of the website consulted: "Write down what URL you accessed to find this information"	Monitoring-Testing	Metacognitive
	Prompt to help students to search for specific information	Steering-Monitoring	Strategic
Scanning-processing information	Worksheet to identify the main content of a website	Steering-Monitoring	Procedural-Conceptual
	Pop-up message: "Before clicking the links, look at the website's structure (index, navigation menu,...)"	Steering-Monitoring	Procedural-Strategic
	Pop-up message: "You don't need the non-necessary-information"	Monitoring	Procedural-Conceptual
	Workspace to gather specific information from a website and compare it	Steering-Monitoring	Procedural-Strategic
	Pop-up message to keep in mind the problem to be solved	Orientation	Conceptual-Strategic
	Pop-up message: "You can't learn if you don't link the new information with what you already knew"	Monitoring	Procedural-Metacognitive
	Worksheet to organize information previously gathered	Steering-Monitoring	Procedural-Conceptual
Organizing-presenting info	Pop-up message to remember the problem to be solved	Orientation	Conceptual-Strategic
	Workspaces to plan a report	Steering	Strategic
	Pop-up message: "Before writing, please think!"	Steering	Procedural-Conceptual
	Writing template	Steering-Monitoring	Procedural
	Pop-up message to guide for assessment of the final answer or product	Testing	Procedural-Strategic

Figure 9 presents an example of a scaffolded section of one of the Web-based instructional tasks, which was entitled: *Toxic waste management*. This task presented the problem that a toxic liquid has been spilled on the street next to a school and students had to try and solve it by using the information from the WWW. Students were guided along four steps: first, investigating the chemical characteristics of the liquid spilled; second, identifying good and bad decisions regarding packaging and storage of the chemical liquid; third, figuring out how to clean up the spilled substance; and, finally, writing a report addressed to environment specialists that included all the details of their researching[12].

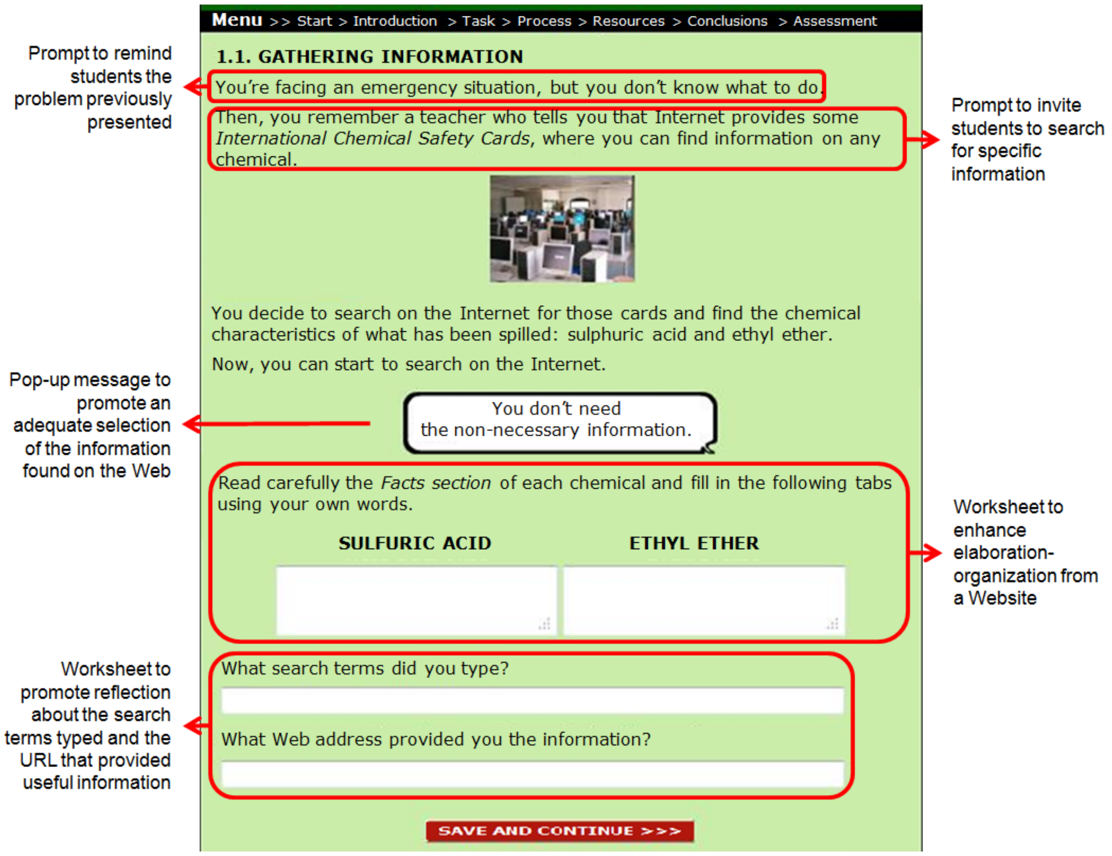

Figure 9. A section of a Web-based instructional activity and examples of scaffolds displays (translated from Catalan)

* * *

[12] To access the entire activity, click on the following link: http://contic.udl.cat/exemples/Gestion_de_residuos_toxicos/inicio.htm.

In this chapter, we presented the two sources that fostered the design of our IPS instructional proposal. The first source was the analyses of learning and teaching methods that involve problem-solving processes: IBL, CBL, PBL, PjBL, and ChBL methods. That analysis allowed us to extract key features to consider in our methodological and instructional intervention to enhance IPS cognitive processes in secondary students. The second source was the consideration of a set of research studies on IPS instruction addressed to secondary students and embedded in the scholar context. That analysis led us to conclude that embedded IPS instruction studies in Secondary Education are scarce, since most of them are implemented as separated courses, loosely connected to the curricular contents. Other conclusions were the need of developing the IPS process as a whole and the importance of transferring these skills to other contexts.

These conclusions steered us to consider as key principles of our instruction the following: *embedding* the instruction in IPS skills in authentic curricular activities, *structuring* the IPS process, and *supporting* the students’ problem resolution with specific scaffolds. These principles were described in detail in this chapter, as well as the design of the instructional intervention considered in this dissertation in order to assess its incidence in secondary students.

In the following chapter we will focus in the methodological frame that structures the empirical part of this dissertation, and in the subsequent chapters we will present four research studies, whose main objective is to give insight into the IPS cognitive processes: skills, sub-skills, and regulation activities.

Chapter 4. Research design

The theoretical and methodological contributions reviewed in the two previous chapters –the IPS process and learning and instructional methods that involve IPS– constitute the core from which our research has originated. Furthermore, another important starting point of our work is the research group in which this dissertation has originated from. The research reported in this dissertation is part of a larger study that deals with the promotion of the secondary students' digital literacy with the regular use of the Internet in everyday classrooms. This study has been conducted by the research group COnTIC –*Context and Cognition mediated by Information and Communication Technologies*[13]–, a consolidated research group recognized by the *Generalitat de Catalunya,* and led by Dr. Manoli Pifarré (*Universitat de Lleida*). In this section, this research line is introduced in order to better understand how the research presented in this dissertation is conceived.

The main aim of this group research line is to contribute and promote the digital literacy of secondary students. This research departs from the indication of the *e*Learning Action Plan (European Commission, 2000) about the use of new technologies and the Internet to improve the quality of students' learning as one of the main challenges of European Education. Students need to develop a set of specific skills and procedures to allow them to exploit the potential of the new information and communication technologies and the Internet as a learning tool. Among these abilities, procedures and strategies, the following four groups stand out: (a) *strategies of information searching*: strategies that allow students to find the information they need to solve a problem –intentional use of search engines, selection of key words, regulation of the process; (b) *specific reading strategies*: strategies that allow information to be interpreted from the new formats of the information present on the Internet; (c) *strategies to analyse the most relevant information*; and (d) *strategies to organize and*

[13] http://contic.udl.cat

synthesize the information selected on the Internet –summaries, schemes, conceptual maps, graphics.

However, the development of this set of strategies in all students, and especially those who have learning difficulties, does not occur spontaneously through the simple interaction of student and technologies. Educational research points out that secondary and higher education students present difficulties in searching and tackling the Internet information to learn (Guinee et al., 2003; Pejtersen & Fidel, 1999). Findings obtained by studies conducted by our group –COnTIC– also follow this fashion. Quantitative and qualitative analyses of the performance of 154 secondary students have led us to the following main conclusions (Gòdia & Pifarré, 2005; Pifarré & Gòdia, 2006; Pifarré, Martorell, & Gòdia, 2006):

- In reference to the perception of the Internet as a tool to learn: 86% of the students considered the Internet as a communication system; few students (14%) introduced in the definition of the Internet elements of working and learning; 65% of students indicated that the last activity for which they were connected to the Internet was to use electronic mail.
- As regards the strategies of information searching on the Internet, students showed a poor use of search engines: they are not able to take advantage of the potential of information of the search engine use; they do not use options to define and refine the search; they normally do not use Boolean operators and fail in the selection of webpages. In addition, they begin searching for information on the Internet without any delineation of the objectives and any planning of the process.
- In relation with their strategies for reading, selection and use of the information on the Internet, these results showed that the reading of the students of the information on a webpage was very quick, intuitive and superficial –students usually performed rapid displacement by scrolling.
- Regarding the strategies of students for analysis, organization and synthesis of the information present in the network, the majority of the students "copied and pasted" information. On a few occasions pupils integrated and discussed the information found on the Internet.

Furthermore, the mediation of symbolic tools, as the Internet, can impact mental activity and learning processes of students (Salomon, Perkins, & Globerson, 1991).

Thus, the following was needed to analyse: what cognitive processes are required for the use of the Internet to learn, which learning processes can be developed by secondary students when using the WWW on a regular basis and in a continuous way at school, and which educational variables of the context can be critical to encourage this kind of learning processes. To gain knowledge in all of these questions, the research group continued with a further step, which persecutes the aim of contributing to promote the digital literacy of secondary students in everyday classrooms. Therefore, the main objectives of this project are the following:

(1) To evaluate which strategies and skills are necessary to develop in secondary students in order that they could use, manage and integrate Web information with learning purposes.

(2) To explore which curricular contents of technology, maths, sciences, and social sciences can be studied using the Internet.

(3) To design and to implement during la ong period of time –three academic years– specific instructional processes in the areas of technology, maths, sciences, and social sciences, aimed at increasing the cognitive processes of searching, managing, and integrating information on the WWW of secondary school students while learning curricular contents.

(4) To evaluate the incidence of Internet mediation in three variables: a) students' leaning results; b) students' learning processes: cognitive and metacognitive processes, and c) social interaction and collaborative development among peers.

(5) To describe the principles and educational variables which must include an instructional model aimed at increasing the strategies of the search, management, and integration of information from the WWW for learning curricular contents in compulsory secondary education.

(6) To design an educational Website that contains the main conclusions of the research project, learning activities using the Internet and different educational Web resources to promote the use of the Internet as a learning tool in Secondary Education.

The participants of this research project were 180 students who belonged to three comparable urban schools in the city of Lleida. This sample was divided into two groups: an experimental group (120 students) and a control group (60 students). The students were participants of this project during three academic years, which corresponds to their 7th, 8th and 9th years of Secondary Education.

The data collection procedure consisted of several instruments, such as ScreenCam Software or logfiles, video, and products obtained by students; it was executed in four process stages (pre-test, post-test 1, post-test 2, post-test 3), as well as during the instructional process[14]. The data analyses consists in qualitative and quantitative data analyses and part of the results of this project are available in this dissertation as in previous group publications (i.e., Argelagós & Pifarré, 2009; Argelagós & Pifarré, 2009b; Guijosa & Sanuy, 2009; Guijosa, Sanuy, & Pifarré, 2009; Pifarré & Argelagós, 2008; Sanuy & Guijosa, 2011).

* * *

After explaining the context from which this dissertation departs, and taking into consideration the theoretical and methodological contributions from Chapters 2 and 3, in this chapter we will present the main objectives that guide the empirical part of this dissertation. To accomplish the general objectives, methodological and empirical options have been taken. Methodological issues will be raised in this chapter, as regards the kind of methods used in this dissertation. Empirical options about how the pieces of research presented in this report have been conducted will be introduced. Particularly, the four studies conducted in this dissertation to accomplish the general objectives also will be introduced in this chapter. We will present the four studies that take part in this dissertation and their constituent elements, in order to make understandable the relationship between those research studies.

[14] Instructional process is more detailed explained in Chapter 3 (section 3) of this dissertation.

1. Research objectives

The main objectives of this dissertation are based on three objectives of the COnTIC's research project presented in the previous section: (a) to evaluate which strategies and skills are necessary to develop in secondary students in order they could use, manage and integrate Web information with learning purposes (*1st objective of the COnTIC research project*); (b) to evaluate the incidence of the Internet mediation in three variables: the students' learning results and the students' learning processes – cognitive and metacognitive (*4th objective of the COnTIC research project*), and (c) to describe the principles and educational variables which must include an instructional model aimed at increasing the strategies of search, management and integration of information from the Internet for learning curricular contents in compulsory secondary education (*5th objective of the COnTIC research project*).

In this context, and in light of the theoretical contributions presented in Chapters 2 and 3 about the IPS process, the main purpose of our dissertation is, on the one hand, to **identify and describe the main challenges that secondary students should overcome to solve IPS** more efficiently and, on the other hand, to study the **effect of embedded structured and supported IPS instruction** on cognitive processes (skills, sub-skills, and regulation) and task performance. In addition, this research aims to draw **conclusions and educational implications** for teachers –and specifically, for the main educational agents: classrooms teachers, in order to provide guidelines to help secondary students to enhance their IPS processes while learning curricular contents at school.

In order to accomplish these main purposes, in this dissertation we carried out four different research studies. In the following, we specify the objectives and their correspondent studies:

- To compare different **techniques** to analyse the **cognitive processes** involved in information-problem solving: "logfiles", "eye-movements", and "cued retrospective reports based on own eye-movements". *[STUDY 1]*

- To provide **detailed analyses** of the **challenges** that secondary students face while solving an information task in their **everyday classrooms**, regarding their IPS cognitive process (constituent skills and sub-skills) and product (answers given and essays written by students). *[STUDY 2]*
- To draw **inferences** about the **educational intervention** needed by students to develop efficient IPS while using the Web to learn curricular contents at school. *[STUDY 2]*
- To analyse the differences between students who participated in an **embedded IPS instruction** and students who did not participate, regarding the development of **IPS skills** and sub-skills during the resolution of an IPS task. *[STUDY 3]*
- To analyse the differences between students who participated in an **embedded IPS instruction** and students who did not participate, regarding the **task performance** (in terms of results). *[STUDY 3]*
- To analyse the **correlations** between the **IPS process** followed to solve a problem using Web information, and the **product** obtained as a result of the resolution of that problem, as well as the correlations between the skills and sub-skills related to the IPS process. *[STUDY 2 and STUDY 3]*
- To select **representative cases** to illustrate different kinds of IPS processes. *[STUDY 4]*
- To provide a **detailed and qualitative account** of how secondary students solve an IPS task. *[STUDY 4]*
- To identify the cognitive processes involved in IPS (**skills**, **sub-skills** and **regulation activities)** that have **more incidence** in the students' ability to solve a problem using digital information on the Web. *[STUDY 4]*

In the next section, we will describe the general methodological approach of this dissertation. Afterwards, we will describe in more detail each research study and their features, which will contribute to better comprehending the cohesion between them.

2. Methodological approach

The four studies that compose the empirical section of this dissertation combine a qualitative and quantitative approach in the data analyses. According to Flick (2004), the variety of approaches and methods can be interpreted as access to the phenomenon of study from various sources that reveal aspects and levels that can be complementary. In this regard, it should be noticed that, for the combination of methods, according to the same author, the election responds directly to the object of the research study and the guideline questions raised.

In vein with this basis, we opted for two decisions to justify our subsequent choices about the collection of relevant data and its organization and analysis. The first decision has to do with a **methodological approach that combines both qualitative and quantitative methods**, that is more adjusted to the specific IPS data, as explained below. The second decision concerns the choice of **case studies** as a methodological option. This approach shows a "comprehensive" point of view, which means, among other things and following Stake (1995), that this approach is always associated with the context. In the following, we expand both decisions framing them in the educational context (in a general view) and in the IPS research context (in particular).

2.1. Combination of methods in information-problem solving research

An extensive review of research on the information-problem solving process (see Chapters 2 and 3 of this dissertation) allowed us to identify three relevant methodological approaches for the study of IPS skills: qualitative, quantitative, and the combination of both methods.

The **qualitative methodological approach** has been used in many studies about web-search or information-problem solving skills. For example, Hoffman et al. (2003) analysed the IPS task-resolution by means of logfiles, interviews and videos in order to give insight in a qualitative way into the content understanding, the search and assess strategies, and the quality of online resources visited by primary students. De Vries et al. (2008) carried out observations, interviews and assessed group products in order to analyse the reflective Web-searching of students. Wang et al. (2011) used observations in classrooms, self reported questionnaires, interviews and student assignments to assess their learning motivation and information literacy. Feddes et al., (2003) carried out an in-depth interview with undergraduate students to gain insight about strategic knowledge concerning each skill of the IPS process. Other studies also applied qualitative methods to study IPS skills (i.e., Ge & Land, 2003; Land & Green, 2000; Oliver & Hannafin, 2001; Printchard & Cartwright, 2004; Spink et al., 2010; Walton & Helworth, 2011). A qualitative approach can contribute to a **deeper understanding of the processes and the ways in which they are performed**.

The **quantitative methodological approach** was also carried out to analyse how subjects solve information problem tasks. For instance, Badilla-Quintana et al., (2011) administered questionnaires to secondary students who had been working with technological equipment in their classrooms; this study also analysed task-resolution logfiles and the students' answers to the task; the data were examined in a quantitative way to assess the computing tools knowledge and management as well as the digital literacy of students. Colaric (2003) quantitatively analysed secondary student questionnaires about their search engine use and queries while Web searching. Sanchez et al., (2006) calculated scores related to higher education student assignments and essays in order to analyse their evaluation of the source and the quality of Web information. Other studies also were immersed in the quantitative approach (i.e, Gerjets & Hellenthal-Schorr, 2008). The quantitative methodology of research allows **calculating** group means and deviations, percentages, **statistical analyses**, and **comparing group data** in order to more easily **generalize** conclusions.

Finally, the **combination of qualitative and quantitative methods** is also possible and fruitful in research on IPS. In addition, it is recommended in order to enrich the understanding in IPS processes, since qualitative and quantitative methods complement one another due to the convergence of the advantages retrieved by each of them. Some studies combined data obtained by qualitative techniques with data obtained by quantitative techniques to complement one another; for instance, Kuiper et al. (2008) observed lessons, interviewed teachers, consulted teacher diaries, and also administered questionnaires to students. Other studies used the same techniques to qualitatively assess the data and then convert it into numbers to be quantitatively managed; for example, Britt & Aglinskas (2002) analysed student note sheets, essays, and answers in order to obtain numeric data to be statistically analysed; Walraven et al. (2010) used a coding scheme to code think-aloud protocols and then they calculated and compared group means and standard deviations.

The objectives of this research dissertation, which were introduced in the previous section, are immersed in this third approach, the so-called **multimethod approach**, which combines qualitative and quantitative methods in order to complement the data obtained by each approach and to enrich the insight of the IPS process. Qualitative methodology will allow us to more deeply understand the IPS processes performed by students, whereas the quantitative approach will contribute to the comparisons between groups by means of statistical and countable measurements, as we will expand in further sections. The combination of data analysed in qualitative and quantitative ways, as well as the combination of both methods in the analyses of the same data, will contribute to a **richer analysis, understanding, and generalization of the IPS processes** performed by secondary students that participated in this research, and also in **more robust, triangulated conclusions**.

2.2. Case study as a tool to analyse the information-problem solving process

The case study is considered a relevant and viable alternative in educational research (Yin, 2006). It also has become one of the methodologies most present in the research on interactive processes in electronic environments for teaching and learning (Schrire, 2006; Xin, 2002). In the specific field of IPS process or Web search, case studies have been widely used in this field of research. For example, Mistler-Jackson and Songer (2000) carried out a case study on the influence of a particular technology-rich program on the students' motivation levels, and stated that attitudes such as student engagement and motivation may affect the quality and nature of understandings that students develop while using the Internet. Pritchard et al. (2004) also explored the notion of engagement by analysing a case study based on a small-scale research project in a primary school classroom in order to illustrate the difficulties that arise when children deal with Internet information. Oliver & Hannafin (2001) conducted a qualitative case study focused on the nature of science learning through open-ended problem solving with eighth graders to analyse the way in which students derived accurate mental models.

In addition, MaKinster et al. (2002) examined searching patterns of students using the Web as a science information resource by means of cases selected according successful or unsuccessful student experiences; and the detailed case descriptions of the students' experiences facilitated discussion about educational guidelines to efficiently integrate the Web in their classrooms. Barron (2000) also selected the case study groups for robust differences in the quality of their written solutions to a problem and parallel differences in the quality of the group members' interaction; this study investigated the interactive processes among group partners and the relationship of these processes to IPS outcomes; the case study offered a distinctive strategy for examining small group learning in collaborative projects. In a similar vein, Ge & Land (2003) conducted a multiple-case study to examine the peer interactions in scaffolding undergraduate student IPS processes, and the study suggested that the peer interaction process itself must be guided and monitored with various strategies in order to maximize its benefits.

According to Yin (1994, 2006) and Stake (1995), a case study is suited for extensive research and in-depth analyses of phenomena, it takes into account the conditions of the **context** in which they appear and attends to **multiple and complementary sources** of evidence to **identify, describe, and understand the phenomena through triangulation**. The selection of a case, or a set of cases, is carried out from its typical character in relation to the objectives of the research, always obeying to criterion of "understanding". When a set of cases are studied as a whole, through a combination of relevant features, a **comprehensive picture** of the phenomenon is retrieved.

It should be noticed that, according to Yin (2006), a case study can be a unique case study or a multiple case study. The distinction between one or another design choice is that more than one case study allows strengthening conclusions and analytical generalizations of analysed cases and other cases with similar theoretical conditions, while an unique case study requires exclusivity and is focused on the same attention. The assumption is that multiple instances can replicate analysis and therefore offer the possibility to deepen the dynamics of what is studied at the same time to produce evidence.

Finally, the case study method is not associated directly to a form in particular of collection and analysis of data, whether qualitative or quantitative, but rather the use of various methods is considered paramount. In this regard, Yin (2006) distinguishes between cases that may be based on a strongly quantitative approach studies and case studies that can be based on both quantitative and qualitative approach. In any case, and regardless of the approach used, the author draws attention about the fact that in the case study the generalization is not related or dependent on statistical generalization, but it is associated with the **analytic generalization based on the possibility of inferences** that, thanks to the logic of the explanatory reasoning, can be extended to other cases.

In this dissertation, we analyse some data by means of a case study. In study 1 and 2, we describe the IPS sequence performed by one of the participants of each study by combining qualitative and quantitative data analyses. In study 4, we orchestrated a set of cases to better understand their key IPS skills and to draw stronger conclusions and educational implications for instruction. We adopted the case study methodological approach because it is able to **illustrate** the difficulties that arise with children while using the Internet (Pritchard et al., 2004), offers a **distinctive strategy for examining IPS processes and learning** (Barron, 2009), and **facilitates discussion about educational guidelines** due to the detailed descriptions that student experiences allowed in case study methodology (MaKinster et al., 2002).

* * *

As a conclusion of this methodological section, we adopted the **multimethod approach**, as being the combination of data analysed in qualitative and quantitative ways in order to obtain a richer understanding and generalization of the IPS processes as well as stronger findings and conclusions. In addition, the election of the **case-study** method will contribute in the detailed context-based illustration, explanation and examination of the IPS processes of the students who participated in this research dissertation.

3. Techniques used in this research study

In previous sections, we explained the need to employ the multimethod and case study as the methodological approach of this dissertation. Furthermore, the set of techniques used to collect the data is also a critical point to be considered, due to the importance of the particularities of each technique and the kind of information that each one can retrieve, which will impact the analyses of the information and, thus, the findings and conclusions drawn.

Therefore, different kinds of techniques can be used to measure cognitive processes involved in IPS: (1) *observational techniques*, that can give insight in the participants' behaviour during an IPS task performance; (2) *perceptual process-tracing techniques,* which concern perceptual-visual processes that cannot be observed from outside; and (3) *reporting techniques,* which can retrieve information given by the participants about their thoughts or opinions. In the following paragraphs, we expand each set of techniques and present the techniques chosen in this research dissertation: *logfiles*, *eye-movements*, and *cued-retrospective reports*.

(1) **Observational techniques** are recommended when a realistic view of participants is required (van Deursen, 2010) because interpretations of skills depend on the context (Talja, 2005). Observational techniques as, for instance, *field notes* or *video recording of the classroom* have been used in several studies (i.e., Hoffman et al, 2003; Kafai et al., 2007). They capture the environment, behaviour and other points of the context and the participants; however these techniques do not capture the detailed processes occurred during an IPS task.

In order to overcome this limitation, in this research, a **logfile technique** will be used as a technique to collect data. This technique is also a form of observation, but only of the screen alone, and permits the analyses of fine-grained student actions during the process of a resolution of an IPS task (Arroyo & Wolf, 2005).

Logfiles are digital recordings of the changes over time on the computer screen. This technique provides information on *overt actions* made on the screen during the task, i.e.: search terms used, results selected in a SERP, webpages visited, answers provided in the task by each participant, etc. Several participants can be easily recorded at the same time by means of this technique. Moreover, the logfile technique has the advantage of unobtrusively recording real interactions by real users in the pursuit of real information needs in the complex Web information environment.

The logfile technique has been used in many studies about Web search and evaluation processes (Kuiper, Volman, & Terwel, 2008; MaKinster, Beghetto, & Plucker, 2002; Spink, Danby, Mallan, & Butler, 2010; Tu, Shis, & Tsai, 2008), regulation support (Manlove, Lanzonder, & de Jong, 2006), collaborative learning (Gassner, Jansen, Harrer, Herrmann, & Hoppe, 2003; Nurmela, Lehtinen, & Palonen, 1999; Nasirifard, Peristeras, Hayes, & Deker, 2009), artificial intelligence (Arroyo & Woolf, 2005; Roll, Aleven, & Koedinger, 2010), and virtual environments in general (Catledge & Pitkow, 1995; Kafai, Feldon, Fields, Giang, & Quintero, 2007), amongst other things. Those studies reported the following kind of retrieved information: searching strategies (Makinster et al., 2002; Tu et al., 2008), navigation strategies (Catledge & Pitkow, 1995), information behaviour and information literacy (Spink et al., 2010), actions such as locations visited, time spent, chat content, speed of response, etc. (Kafai et al., 2007), and observable students behaviour to infer student learning and attitudes (Arroyo & Wolf, 2005). However, the participants' covert processes cannot be accessed by logfiles, because this technique only observes the overt actions.

(2) **Perceptual process-tracing techniques** concern visual or perceptual processes, which are covert processes. **Eye-movement techniques** provide unique information on covert processes concerning what is visually attended to, in what order, and for how long (Holmqvist, Nyström, Andersson, Dewhurst, Jarodzka, & van de Weijer, 2011). The data retrieved by this technique provide information on general eye-movement parameters, like the number and duration of fixations, saccades, and blinks. More importantly, so-called areas-of-interest (AOI) analyses can be done. For this purpose the webpages are divided into semantic homogenous areas (e.g., navigation buttons, written text, text boxes, etc.). Based on this division, it can be calculated in which order participants inspected the website, which elements were processed the most and which were entirely skipped. Increasingly, eye-movement techniques are used for research on how students study learning materials (cf. two special issues on this topic: Scheiter & van Gog, 2010; van Gog & Scheiter, 2010).

This technique is especially used to analyse multimedia learning processes in detail, to focus on the effects on visual attention of animations (for example: Hegarty, 1992; Schmidt-Weigand, Kohnert & Glowalla, 2010), text and picture representations (Graesser, Lu, Olde, Cooper-Pye, & Whitten, 2005; Holsanova, Holmberg, & Holmqvist, 2009), to enhance multimedia materials (de Koning et al, 2010; Boucheix & Lowe, 2010), to find differences between experts and novices in order to enhance the instruction (Jarodzka, Scheiter, Gerjets, & van Gog, 2010; Canham & Hegarty, 2010), to stimulate reflection or reasoning (Grant & Spivey, 2003; van Gog et al., 2005), or to analyse the visual exploration of a SERP during a web-search (Dinet, Bastien, & Kitajima, 2010; Kammerer & Gerjets, 2012).

As opposed to the logfile technique, the acquisition or utilisation of eye-movement techniques is expensive and thus, it is difficult to record more than one person at the same time. As with logfiles, eye-movements cannot retrieve the participant's thoughts though.

(3) **Reporting techniques**, in which participants report their interest, experiences, attitudes or motivation, have also been used in IPS, and the two most widely used are *concurrent* and *retrospective reporting* (van Gog, Kester, Nievelstein, Giesbers, & Paas, 2009). Concurrent reporting, as thinking-aloud, requires participants to verbalize all thoughts that come to mind during task performance. Retrospective reporting, on the other hand, requires participants to report the thoughts they had while they were working on a task, immediately after task performance (Conrad, Blair, & Tracy, 1999; Ericsson & Simon, 1993; van Someren, Barnard, & Sandberg, 1994). Both techniques allow for valid inferences about the processes underlying task performance (Jarodzka et al., 2010; Schwonke, et al., 2009). However, concurrent reporting may become difficult to maintain with novice learners or with highly complex tasks due to the high cognitive load needed (van Gog, 2006) and may be potentially compromised when the task animations contains spoken text or music (van Gog et al., 2009). Alternatively, retrospective reporting, which has less problems in terms of cognitive load or audio content, can be used.

In the attempt to avoid the disadvantages of those reporting techniques, the **cued-retrospective report technique** proposed by van Gog et al. (2005) is the third technique used in this research. Cued-retrospective reporting is a technique to capture covert thought processes. This technique elicits verbalizations of thought processes *after* task performance cued by a replay of one owns eye-movements (Van Gog et al, 2005). Research by van Gog, Paas, van Merriënboer and Witte (2005) revealed, that the same kind of cognitive processes could be retrieved from thinking aloud and cued-retrospective reporting. In this vein, the cued-retrospective reports technique is being used with IPS tasks (Brand-Gruwel, van Meeuwen, & van Gog, 2008; Kammerer, Bråten, Gerjets, & Strømsø, 2010; Schwonke, Berthold, & Renkl, 2009; van Gog, et al., 2005). In those studies, both types of information (logfiles and eye-movements) served as cues for the retrospective report. Other studies used cued-retrospective reports when the eye-movements constituted the sole source of information in the recording (de Koning et al., 2010; Jarodzka et al., 2010).

Other *report techniques* could still be considered: such as *inventories, scales, questionnaires, surveys, interviews*, and *focus groups*. These techniques have the ability to present a large amount of questions on a wide variety of skills in a short time, simple scoring, quick processing, and cost effectiveness (Kuhlemeier & Hemker, 2007), but they can have validity problems in specific IPS environments (Hakkarainen et al., 2000).

* * *

In this study, the techniques used to analyse the data are the following three: *logfiles*, *eye-movements,* and *cued retrospective reports*. On the one hand, logfile technique provides information on *overt actions* made on the screen during the IPS task. On the other hand, eye-movement technique provides unique information on covert processes concerning what is visually attended to, in what order, and for how long. However, data retrieved by logfiles and eye-movements require a substantial degree of inferences about underlying cognitive processes, as they do not explain *why* participants execute certain actions or look at certain elements. Cued-retrospective reporting is a technique to capture covert thought processes.

The three techniques selected for this research hold different features, capture diverse kinds of information and serve different purposes in research and education. One important reason for the selection of those three techniques is that all of them are able to successfully unravel cognitive processes underlying task performance without interfering with the IPS processes (e.g., de Koning et al., 2010).

4. Information-problem solving task

Concerning the IPS task performed by participants, it is the same IPS task for the four studies. It is solved individually and it lasts about 45-50 minutes. It is divided into two main parts. In part 1, participants are engaged in completing a concept map to collect information about planet Mars (physical characteristics, orography, atmosphere, climate, and satellites). In part 2, participants have to accomplish three steps: (2.1) explaining, using information from the WWW, the conditions a planet must fulfil to make life possible on it, (2.2) describing the favourable and unfavourable conditions of Mars, and (2.3) writing an argumentative essay that would answer the question of whether it would be possible to install a human colony on Mars, and, if so, what difficulties would have to be overcome, and why (Figure 10).

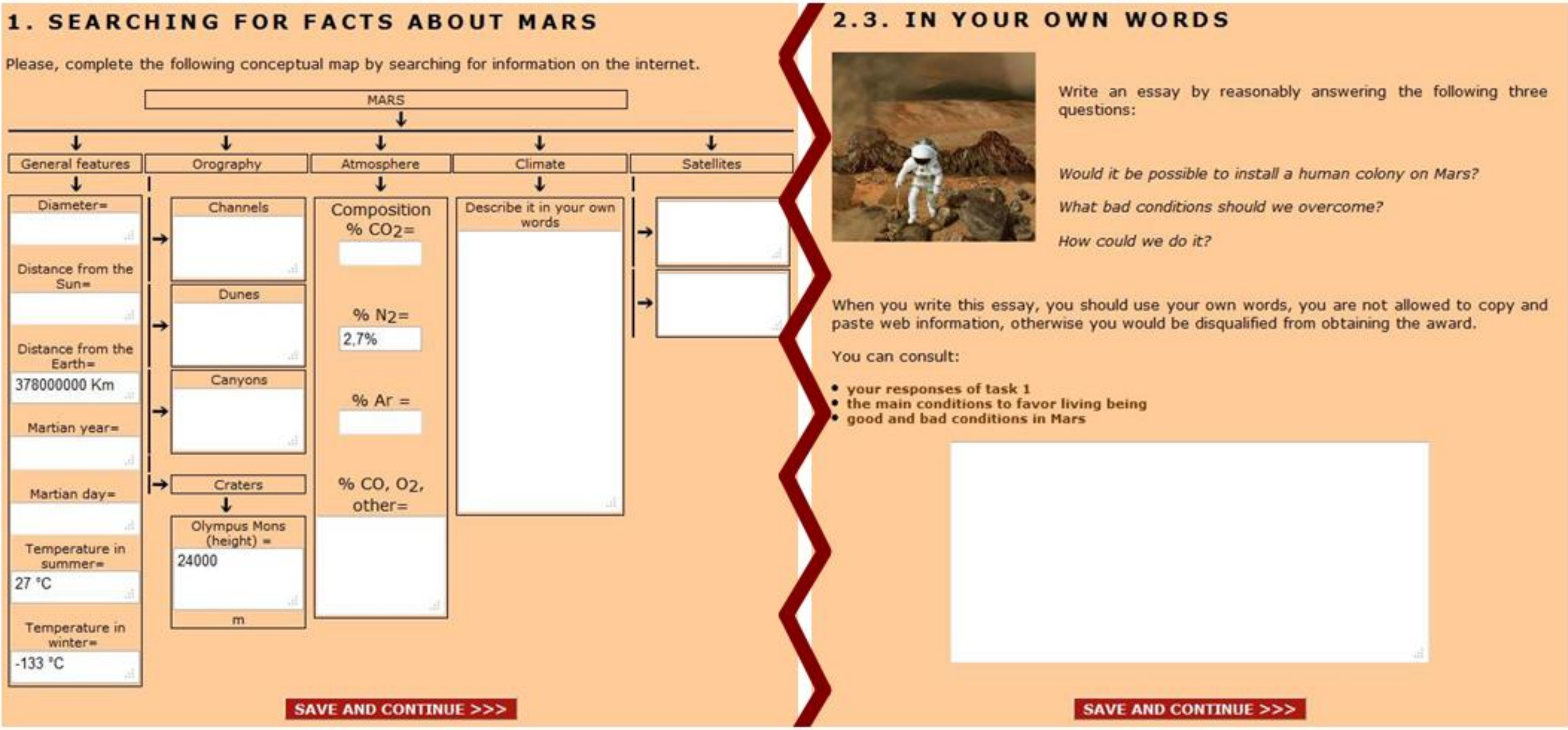

Figure 10. Two different screenshots of the IPS task (translated from Catalan)

5. Data analyses procedure

In the following, we describe the data analyses procedures of each technique used in this dissertation research: logfiles, eye-movements, and cued retrospective reports.

5.1. Data analyses procedure for the data obtained by the logfiles technique

Data retrieved by the logfiles were transcribed as descriptions of all actions made on the screen by means of mouse or keyboard. As a result, logfile protocols were obtained through this transcription process. Each protocol is coded with a coding scheme based on the cognitive processes (skills, sub-skills, and regulation activities) of an IPS model (Brand-Gruwel et al., 2005; Walraven et al., 2009). An inductive-deductive method was used to build up this system: it was refined by analysing samples of the protocols, and with contact with experts[15].

The scoring system itself consists of two types of categories. The first category, *constituent skills* (‘Define the problem’, ‘Search for information’, ‘Scan and Process information’, and ‘Organize and present the information’), is scored in an exclusive way. The second category consists of the *sub-skills* of each constituent skill. The third category, considered only in Study 4 due to its interpretative and context-based style, consists of the regulation activities: orientation, monitoring-steering, and testing. Also the time spent on each category is captured. Tables 6 and 7 show the coding scheme constructed to analyse logfile data.

[15] In this regard, the pre-doctoral research stage at the *Centre for Learning Sciences and Technologies* (CELSTEC) and the discussion sessions with the Dr. Saskia Brand-Gruwel, were clearly useful to construct a definitive coding scheme that is a valid and usable instrument to analyze the data retrieved by logfiles and the data retrieved by cued-retrospective reports.

Table 6. Coding scheme to analyse logfiles data. Column 1 (constituent skills) and column 2 (sub-skills)

COLUMN 1 Constituent skills	COLUMN 2 – Sub-skills		
	Code	Description	EXAMPLES
1. Define the problem (D)	AD	**Analysis of the Demand**: general overview of the task, reading the task. [Analysis is before searching or processing information.]	- Task 1 appears. Keeps placed in the inferior part of the page, below the conceptual map. - Keeps placed in the inferior part of the page, below the conceptual map. - Places in the conceptual map. - Follows the paragraphs of the task. - Select some information. - Places in the blank Diameter.
	CD	**Consulting of the Demand**: coming back to the assignment when is performing other constituents skills (SI, SPI, OPI). [Consulting is after searching or processing information.]	
2. Search for Information (SI)	WAT	Web Address Typing in URL bar.	- Types "Wikipedia" in URL bar.
	STT	Search Terms Typing in search engine.	- Google page appears. Types in the search engine: "mars". - (When an action is CK (because of Paste) and STT, this action will be coded as STT)
	SOU	**Search-engine Options Use**. I.e., "Only in English".	- Clicks "Advanced search".
	SR	**Selection of the Results.** When Search Engine Result Pages (SERP) appears, choosing a result.	- SERP appears. - Places in the results. - Clicks one result.
3. Scan and Process Information (SPI)	LWP	Looking at the Web Page. No action.	- Web page appears. Places in the side of the webpage. - Places in the paragraph about water in Mars. - Webpage appears. Keeps in the side of the page.
	SCAN-SC	**Scanning-Scroll**. Using i.e. the scrollbar or scrollmouse.	- Scrolls down. - Scrolls up.
	IMAGE	Placing at the **image**.	- Places at the image.

4. Organize and Present Information (OPI)	OA	**Objective Answers** typing/deleting, in some of the conceptual map answers.	- Types "6.087km" in the blank of Diameter. - Ctrl+v. - Clicks Paste. (When an action is CK (because of Paste) and OA, this action will be coded as OA)
	EA	Explanation Answers typing/deleting.	- Task 2.1 appears. Types "Water is necessary for life in a planet" in the blank. - Ctrl+v. - Clicks Paste. (When an action in CK (because of Paste) and EA, this action will be coded as EA)
Common aspects in the four previuos Constituents Skills	AP	**Adjusting of the Page** in order to manage the content better.	- Moves the window to fit the page. - Scrolls down. So s/he can see all the page.
	SL	Selection of a Link.	- Clicks in the link "Facts about mars".
	CK	**Click/Keyboard**, such as: clicks, enter, etc.	- Enter. - Clicks "back" button. - Clicks right button. - Clicks Copy.
	TA	**Technical Aspects**, such as: page does not work any more. Paying attention to other elements of the assignment or the web site, such as: how to write, how to come back, etc..	- Tries to move the window, scroll down, minimize, close, but it is not possible. Technical problems or aspects.
	WT	**Waiting Time** when the web-page delays to appear.	- Web page is delayed.

Table 7. Coding scheme to analyse logfile data. Column 3 (Regulation activities, in an interpretative way)

Code	Description	EXAMPLES
O	**Orientation on the task.** Consulting the demand during the task.	
MS	**Monitoring and Steering.** Adequate supervision of one's own performance.	- Types "There are some requirements a planet have to guarantee for life", correcting when mistakes (2 times). - Types "diameter mars", correcting when mistakes (1 time). - Delete "facts about". The new search terms are now: "mars".
T	**Testing**. Written search-terms revising, written answers revising.	- Write or delete some words or letters from the search terms that s/he wrote. - Write or delete some words or letters from the text that s/he wrote.

This coding scheme allows extracting two levels of analysis: (1) a first level (more quantitative level) and (2) a second level of analyses (more qualitative level).

(1) Regarding the **first level of logfile analyses** (more **quantitative** level), three types of information retrieved from the logfiles are analysed. The first type of information refers to the *constituent skills* performed by each participant. In order to get insight in the skills, we first calculate the time the participant spent on each skill by counting the total number of seconds invested in each skill. In addition, we also count the number of times each skill occurred. Hence, time spent and frequencies are calculated for each skill.

The second type of logfile information in this level of analyses refers to the following *sub-skills*: search terms typed, selected results, and processing of the information. Furthermore, for each of these measures a correctness score is calculated.

The third type of logfile data in the first level of analyses is the *task performance*. The answers given by each participant are rated with respect to their quality on a rating scale, ranging from 0 points (incorrect), 0.5 points (incomplete), to 1 point (correct).

(2) As regards the **second level of analyses** (more **qualitative** level), protocols are analysed more in-depth in order to gain insight in the several skills and sub-skills involved in the IPS process. Time spent and frequencies are calculated for each skill and sub-skill performed. In addition, regulation activities are considered in Study 4, since this study was carried out in a more interpretative and qualitative way, taking into consideration the context (Beers, Boshuizen, Kirschner & Gijselaers, 2007), and using a methodological approach of case study. This second level of analysis allows constructing an in-depth analysis of the IPS process performed by participants, and it even can be graphically represented.

5.2. Data analyses procedure for the data obtained by the eye-movement technique

The analysis for the data provided by the eye-movement technique is based in the attention allocation across the task webpage, SERPs, and all other webpages visited. The analyses are administered in the following way.

The task webpage was divided into the Areas Of Interest (AOIs). The eye-movement parameters that are calculated based on these AOIs are described in the following. *Time to first fixation* is the time from entering the website until the participant fixates on the AOI group for the first time and allows inferring which AOIs were attended to first and which last. The *total fixation duration* is the duration of all fixations within all AOIs belonging to an AOI group (in seconds) and allows inferring which AOIs were attended to most. The *number of AOI hits* is the number of times the participant fixated within an AOI group and allows inferring the amount of visual search within an AOI group. The *AOI skip* provides information on how often AOIs or AOI groups were totally skipped. More detailed description of data analyses procedure of eye-movements is presented in Study 1 (Chapter 5).

5.3. Data analyses procedure for the data obtained by the cued-retrospective reports technique

Participant utterances retrieved by the cued-retrospective reports were transcribed verbatim. To analyse the protocols, we also constructed a coding scheme based on the skills, sub-skills, and regulation activities of the IPS model described in Chapter 2 (Brand-Gruwel et al., 2005; Walraven et al., 2009). It was done in a similar way as with the logfile technique. The scoring system itself consists of three types of categories. The first category, the constituent skills, is scored in an exclusive way. The second category consists of the sub-skills of each constituent skill. The third category involves regulation activities (orientation, monitoring-steering, and testing). All the utterances are coded in each protocol for each participant. Tables 8 and 9 show the coding scheme used to analyse the data obtained by the cued-retrospective reports.

Table 8. Coding scheme to analyse the cued-retrospective reports data: ***COLUMN 1 (Constituents skills) and COLUMN 2 (Sub-skills)***

COLUMN 1 Constituent skills	COLUMN 2 – Constituent sub-skills		
	Code	Description	EXAMPLES
1. Define the problem (D)	AD	**Analysis of the Demand**: General overview of the task. [Analysis is <u>before</u> searching or processing information.]	- This is about facts about Mars.
	AD-READ	Analysis of the Demand: Reading the task.	- I was reading the task
	AD-NEED	**Analysis of the Demand**: Determining what information is needed.	- I had to look for the Diameter.
	AD-QUEST	Analysis of the Demand: Formulating own questions to be answer.	- The first impression was: what does this word means.
	AD-PRIOR	Analysis of the Demand: Activating prior knowledge.	- I don't really understand this word: Exobiology.
	AD-PROD	**Analysis of the Demand**: Determining the requirements and constraints of the **product** to be delivered.	- I have to list some conditions in this blank space.
	CD	**Consulting of the Demand**: Coming back to the assignment when is performing other constituents skills (SI, PI, OPI). [Consulting is <u>after</u> searching or processing information.]	- This was about facts about Mars.
	CD-READ	Consulting of the Demand: Reading.	- I was reading the task again.
	CD-NEED	**Consulting of the Demand**: Determining what information is **needed**.	- I had to look for the Diameter. - What was the exact word?
	CD-QUEST	Consulting of the Demand: Formulating own questions to be answer.	- The first impression was: what does this word means
	CD-PRIOR	Consulting of the Demand: Activating prior knowledge.	- I don't really understand this word: Exobiology.
	CD-PROD	**Consulting of the Demand**: Determining the requirements and constraints of the **product** to be delivered.	- I have to list some conditions in this blank space.

2. Search for Information (SI)	WAT	Web Address Typing in URL bar.	- I typed "wikipedia"
	SEC	Search Engine Choosing.	- I searched on Google.
	STT	Search Terms Typing in search engine.	- I typed "mars" - I changed my search terms…
	SOU	**Search-engine Options Use**. I.e., "Only in English".	- I clicked on "Advanced search".
	SR-A-U	Assessing the Result according to **Usability**: **following the question**, public, topicality, language, structural information, amount of information, etc.	- I read the tittle. - I read the summary. - My first thought was just looking on a general webpage, so Wikipedia was my first suggestion.
	SR-A-R	Assessing the Result according to **Reliability**: (**author**, attributes, references / links, same information at multiple sites, **objectivity**, primary / secondary, target, etc.).	- I was looking at the hits and looking at who was the author of the website.
	SR-A-UR	Assessing the Result according to **Usability and Reliability.**	- I was looking at the hits and looking at who was the author of the website. So, I was thinking: Well, the NASA is the probably quite good because I can find useful information there!
	SR-A	Assessing the Result, **without** explanations about the criteria.	- This is good! - I chose a better website.
3. Scan and Process Information (SPI)	LWP	Looking at the Web Page. No specified action.	- I was looking at the Web Page… - I searched for it
	SCAN-SC	**Scanning-Scroll**. Using i.e. the scrollbar or scrollmouse.	- I scanned the site…
	SCAN-FW	**Scanning-Following words**. Following some words, not entire sentences.	- I scanned the site…
	READ-FS	**Reading- Following Sentences**. Following at least an entire sentence or sintagma with sense.	- I read…
	IMAGE	Placing at the **image**.	- I looked at the image.
	SCAN-ELAB	**Scanning-Elaborate.** Elaborating the content scanned.	- They are facts but another facts that I really want. - I was responding to at two places.

			- Well, why I don't just type for example distance from Mars to the earth or distance from Mars to the sun, it can be maybe quicker to find out the answers, so I can't read so much from Wikipedia. - And then I think: Maybe it's too new. - And I have some ideas about, ok, here I found that biology is to describe what kind of conditions the other planets should need if you may be human beings who want to life there. - I don't know what this is, I don't know what the title means for me. - I found my answers here, because they listed different types of criteria and what life means, and what each some criteria is.
	READ-ELAB	**Reading-Elaborate.** Elaborating the content read.	- This is when I found all the information.
	AWS-A-U	Assessing the Web Site according to **Usability**: **following the question**, public, topicality, language, structural information, amount of information, etc.	
	AWS-A-R	Assessing the Web Site according to **Reliability**: (**author**, attributes, references / links, same information at multiple sites, **objectivity**, primary / secondary, target, etc.).	- I can trust in this site because it's from the NASA. - But I don't know who wrote this!
	AWS-A-UR	Assessing the Web Site according to **Usability and Reliability.**	- This was the best site: I found some of my answers and It was written by experts.
	AWS-A	Assessing the Web Site, **without** explanations about the criteria.	- This Web Site is good!

4. Organize and Present Information (OPI)	OA	**Objective Answers** typing, in some of the conceptual map answers.	- I typed the answer. - I pasted the answer. - I typed that … - I copied and pasted it. - I find something...
	EA	Explanation Answers typing/deleting.	- I typed something about water… - I typed the answer on Climate… - I copied and pasted it. - I find something...
	EA-FORM	**Reformulating** sentences while typing.	- Maybe it's better to write that the water is an essential conditions for life…
	EA-ELAB	**Elaborate** the content of the text written or to write.	- And then I write: water is really very important because I heard it and think about this, and I'm very sure this is one of the conditions. So I just wrote it down immediately.
	EA-STRUC	Elaborate the **Structure** of the text written or to write.	- I 'm writing it down in a more structured way.
Common aspects in the four previous Constituents Skills	AP	**Adjusting of the Page** in order to manage the content better.	- I tried to fit the page… - I tried to see better…
	SL	Selection of the Link.	- I was looking at the links… - I chose the link "X"…
	CK	**Click/Keyboard**, such as: clicks, enter, etc.	- I clicked Enter. - I came back… - I clicked the right button to copy… - I copied…
	TA	**Technical Aspects**, such as: page does not work anymore. Paying attention to other elements of the assignment or the web site, such as: how to write, how to come back, etc..	- I tried to find out how I can search in the internet.. - I tried to move the window… - I tried to minimize… - I tried to close the window… - I tried to fill out the distance, but it wasn't possible…
	WT	**Waiting Time** when the web-page delays to appear.	- Web page is delayed. - Here I was waiting…

Table 9. Coding scheme to analyse the cued-retrospective reports data: ***COLUMN 3 (Regulation activities)***

COLUMN 3 – Regulation activities		
Code	Description	EXAMPLES
O-TASK	**Orientation**. Keeping in mind the **task** to solve, while searching, scanning, processing information or organizing or answering.	- Now I have some clue, but I still can find the answer about conditions for life. - Maybe it's too new… (before was talking about Exobiology) - I need to find something about the climate on Mars!
O-TIME	**Orientation**. Being aware of the time available.	- I clicked several different web sites to see which is better, because I have limited time. -No I have no time to read. So I had to change my key words.
MS	**Monitoring and Steering.** Adequate supervision of one's owns performance and **decisions**. Thinking about the task, from a higher approach.	- I went to Google first, because I don't know what it means. - I need Google. - I decided to change my key words. - I had to change my words. - I couldn't find it. - I thought I would find everything in this nice table. - This is what I found. - I was searching and I couldn't find it the real related answers to these blanks. - (Maybe I can try the other web site) to see where I can find something. - I couldn't write it by my own words, actually, because I would make mistakes, so… I just copied them. - I tried a different way. - Then it's easy to find the answers. - It was a difficult task. - It was nice / interesting / a bit confused. - I think: ok.
T	**Testing**. Written search-terms revising, written answers revising. It includes SIZE, QUAL, STYL, COMP, OVER (indistinctly).	
T-SIZE	Checking the **size** of the text (or search terms).	- It's too long!
T-QUAL	Checking the **quality** of the text (or search terms).	- I think it's a nice text.
T-STYL	Checking the **style** of the text (or search terms).	- This sentence doesn't looks like very good.
T-COMP	Checking the **completeness** of the text (or search terms).	- I think my text already is completed.
T-OVER	Checking whether there are **overlap ideas** in the text (or search terms).	- I wrote this idea twice!

Table notes:
- Some utterances were unable to be coded, as “It was a bit slow”, “I don’t remember what I was doing here”, “I don’t know”,…
- Difference between O and MS:
    · O is coded when the specific content to find is expressed (i.e., “I need to find something about the climate on Mars!”; “I couldn’t find the diameter”; Maybe it’s too new… (talking about Exobiology)).
    · MS is coded when the specific content to find is not expressed (i.e., “I couldn’t find it”; “I decided to change my key words”).

6. Studies conducted in this research dissertation

In the previous sections of this chapter, we presented the general objectives of this dissertation (to identify and describe the main challenges on IPS, to study the effect of an IPS instruction, and to draw conclusions and educational implications), the methodological approach followed (multimethod and case study), the techniques selected to analyse the data (logfiles, eye-movements, and cued-retrospective reports), the IPS task, and the data analysis procedure. In this section, we will present the four studies which intend to accomplish the general purposes of this dissertation. Furthermore, in order to give an overview of the empirical section, we will introduce the objectives or research questions of each study, the methodological approach, the techniques used, and the general contribution of the study to the general purpose of the dissertation.

Study 1. Title: *Unravelling cognitive processes involved in information-problem solving: logfiles, eye-movements, and cued-retrospective reports compared* (Chapter 5 of this dissertation).

- The main research question of this study is: What **kind of processes** involved in **IPS** can be retrieved using three **evaluation techniques** – logfiles, eye-movements, and cued retrospective reports?
- The methodological approach applied in this study is the convergence of the **multimethod** and the **case-study**.
- The techniques selected for this study are: **logfiles**, **eye-movements** and **cued-retrospective reports** based on own eye-movements.
- In this study three types of process-tracing techniques are compared to gain insight into the relevant processes underlying the IPS. The conclusions of this study will allow us to decide **which technique will be used** in the following studies that have part of this dissertation.

Study 2. Title: *Secondary student challenges in information-problem solving: some clues for the design of efficient instruction* (Chapter 6 of this dissertation).

- The research objectives of this study are the following three:
    1. To provide **detailed analyses** of the **challenges** that secondary students face while solving an information-problem task in their everyday classrooms, regarding their **IPS process** (constituent skills and sub-skills) and **product** (answers given and essays written by students).
    2. To analyse the **correlations** between the **IPS process** followed to solve a problem using Web information, and the **product** obtained as a result of the resolution of that problem, as well as the correlations between the skills and sub-skills related to the IPS process.
    3. To draw **inferences** about the **educational intervention** needed by students to develop efficient IPS while using the Web to learn curricular contents at school.
- The methodological approach applied in this study is the convergence of the **multimethod** and the **case-study**.
- Considering the conclusions drawn in the first study, the technique used in this study is the **logfile** technique.
- In this study the IPS challenges analysed and the educational implications drawn for the IPS instruction, will be a **starting point to conduct the following study**, about the effect of a IPS instruction at Secondary School.

Study 3. Title: *Improving information-problem solving in Secondary Education through embedded instruction* (Chapter 7 of this dissertation).

- The research questions of this study are the following three:
    1. What are the **differences** between students who participated in the **embedded IPS instruction** and students who did not participate, regarding the development of **IPS skills** and **sub-skills** during the resolution of an IPS task? Do the instructed students show a more expert **web-searching pattern** than the non-instructed students?
    2. Do the instructed students obtain a better **task performance** (in terms of results) than that of non-instructed students?

3. Is there a **correlation** between the process (constituent skills and sub-skills) and the task performance in the IPS tasks executed by the participants?

- The methodological approach applied in this study is **multimethod**, which combines qualitative and quantitative methods, as explained in previous sections.
- The technique used in this study is the **logfile** technique.
- This study will analyse an **embedded, structured and supported IPS instruction** carried out in secondary classrooms. Although this study is the core of this dissertation, it has been supported by the first study (in terms of orientation about the more suitable technique to be used) and by the second study (in terms of specifying and defining the IPS challenges of secondary students). Furthermore, the findings obtained in this study will be **complemented and qualified** by the findings of the fourth study.

Study 4. Title: *Information-problem solving patterns and sequences of secondary students in classroom: a multi-case study* (Chapter 8 of this dissertation).

- The research objectives of this study are the following:
    1. To select **representative cases** to illustrate different kinds of IPS processes.
    2. To provide **detailed and qualitatively accounts** of how secondary students solve an IPS task.
    3. To identify the **IPS skills**, **sub-skills**, and **regulation activities** that have more incidence in the students' ability to solve a problem using digital information on the Web.
- The methodological approach applied in this study is the convergence of **multimethod** and **case-study**. Particularly, more emphasis will be given to the qualitative methodology in this study. Furthermore, a multi-case study methodology will guide the study and will frame the qualitative data analyses.
- The technique used in this study is also the **logfile** technique.
- The findings obtained in this study emphasize the qualitative methodology which will give **more insight into the understanding of the skills and sub-skills** involved in IPS. The multi-case study and the contextualized qualitative

analyses will allow us to identify **regulation activities** that accompany the IPS skills performed by students.

In Table 10, we summarize the main methodological characteristics of each study to show a general overview of the four studies. In the following sections, we describe each study's features and relate them in order to make more understandable the cohesion between the four studies as well as the relationship of each one with the general dissertation purposes.

Table 10. Main methodological characteristics of each study

Studies	Participants	Methods	Techniques and data collection instruments	IPS task	Data analysis procedure
Study 1. TECHNIQUES	17	Qualitative Quantitative Case study	-Logfiles (CamStudio 2.0) -Eye-Tracking (Eye-tracker Tobii 1750) -Cued Retrospective Reports	About Planet Mars	-Coding scheme developed to analyse logfile data -Coding scheme developed to analyse cued retrospective reports data
Study 2. CHALLENGES	40	Qualitative Quantitative Case study	Logfiles	About Planet Mars	-Coding scheme developed to analyse logfile data
Study 3. PRE-POST	40	Qualitative Quantitative	Logfiles	About Planet Mars	-Coding scheme developed to analyse logfile data
Study 4. IPS PATTERNS	6	Quantitative Qualitative Multi-case study	Logfiles	About Planet Mars	-Coding scheme developed to analyse logfile data

6.1. Participants of each study

After the overview presented in the previous section and, in particular, in Table 10, we will focus on the isolated elements of each study: participants, methods, techniques, data collection instruments, IPS task, and data analysis procedure. The first focus will be about the participants of each study.

As can be appreciated in Table 11, the participants of these research studies belong to different origin and contexts. The participants of Study 1 are adults from a research and university centre from the Netherlands, and the participants of Studies 2, 3, and 4 are Secondary Students from Spain.

This sample is considered for Studies 2, 3, and 4; however, each study analyses the sample under different angles and for different complementary purposes. Study 2 takes into account the data of the pre-test of the 40 Spanish Secondary Students to analyse the challenges they face to solve IPS tasks at school. Study 3 compares the pre- and the post-test data of these students considering their condition (experimental or control group) to analyse the effect of the IPS instruction carried out during two academic years. Finally, Study 4 selects a sub-sample of 6 students from the sample of 40, to analyse in a more qualitative and detailed way their IPS patterns and sequences and to gain more insight into the cognitive processes involved in IPS.

Table 11. Participants of each study

Studies	Participants
Study 1. TECHNIQUES	17 PhD students and university staff in the field of the Learning Sciences and Technologies (age *M* = 36.06, SD = 8.45) of the Netherlands.
Study 2. CHALLENGES	40 secondary students from the 7th grade (13-14 year-olds) that belong to three urban schools in the city of Lleida (Spain). (Analysis of the pre-test)
Study 3. PRE-POST	40 secondary students of the 7th and 8th grade (13-15 year-olds) that belong to three urban schools in the city of Lleida (Spain) (The same students than in study 2; comparison between the pre-test and post-test)
Study 4. IPS PATTERNS	6 secondary students of the 7th and 8th grade (13-15 year-olds) that belong to three urban schools in the city of Lleida (Spain) (Sub-sample of the 40 students of Studies 2 and 3)

6.2. Methods and techniques of each study

The second focus is about the methods used in each study. Table 12 shows descriptions of the analyses that are performed in each study, according to a qualitative or quantitative approach (multi-method), and whether the case study approach is applied.

Table 12. Method and descriptions of the analyses performed in each study

Studies	**Methods**	**Descriptions of the analyses performed as regards each method**
Study 1. TECHNIQUES	Qualitative	-Coding of the actions made on the screen by the participants (logfile data) -Analyses of the sequence followed by one student (eye-movement data) -Over time analyses of total fixations performed by one student (eye-movement data) -Coding of the utterances given by the participants (cued retrospective reports data)
	Quantitative	Calculations, means, standard deviations and correlations of the following variables obtained by logfile data: -time spent and frequencies of constituent skills performed -appropriateness score of search terms, selected results and processing of the information -task performance Calculation, means and standard deviations of the following variables obtained by eye-movement data: -Area Of Interest (AOI)'s attention allocation in each webpage. -time to first fixation, total fixations, and number of AOI hits Calculation, means and standard deviations of the following variables obtained by cued retrospective reports data: -number of utterances given by students related to overt actions, attentional processes, cognitive processes, and regulation activities.
	Case study	-Qualitative description of a sequence example of one student (logfile data) -Qualitative, quantitative, and descriptive comparison between the data obtained by the three techniques.
Study 2. CHALLENGES	Quantitative	Calculations, means, standard deviations and correlations of the following variables: -time spent and frequencies of constituent skills performed -appropriateness score of search terms, and selected results -task performance
	Qualitative	-Coding of the actions made on the screen by the participants -Assessment of the search terms and the selected results -Assessment of the task performance –answers' correctness -Coding of the task performance –answers' level of elaboration and explanation
	Case study	-Qualitative and quantitative description of a sequence example of one student (logfile data)

Study 3. PRE-POST	Qualitative	-Coding of the actions made on the screen by the participants -Assessment of the search terms and the selected results -Assessment of the task performance –answer correctness
	Quantitative	Calculations, means, standard deviations and correlations of the following variables: -time spent and frequencies of constituent skills performed -appropriateness score of search terms and selected results -task performance T-test to analyse the differences between experimental and groups Repeated measures ANOVA to identify interaction between instruction and variables measured in the experimental and control groups
Study 4. IPS PATTERNS	Quantitative	Measurements of the following variables: -time spent and frequencies of constituent skills performed -appropriateness score of search terms, selected results and processing of the information -task performance
	Qualitative	Identification of IPS patterns of students Descriptive and illustrative IPS sequences performed by students
	Multi-case study	Quantitative and qualitative analyses of six students

In addition, as was expanded in Section 2.4 of this chapter, several techniques are used in this empirical research. The first study includes three different techniques (logfiles, eye-movements, and cued-retrospective reports based on eye-movements) because the main objective is to compare the type of information retrieved by each technique. This first study follows a within-subject design and its data collection is conducted in a lab. Following the conclusions of Study 1, the other three studies use only one technique –logfiles– and its data collection is carried out in the regular classroom of students. Table 13 shows a summary of techniques, data collection instruments and data collection procedure used in each study.

Table 13. Techniques, data collection instruments and procedure of each study

Studies	**Techniques and data collection instruments**	**Data collection procedures**
Study 1. TECHNIQUES	-Logfiles (CamStudio 2.0: www.camstudio.org) -Eye-movements (Eye-tracker Tobii 1750: www.tobii.com) -Cued-retrospective reports (CamStudio 2.0)	Within-subject design. Participants performed an IPS task in a lab. During task performances, logfiles were captured, and eye-movements were tracked. Afterwards, they reported their thoughts while reviewing their overt actions and eye-movements; verbal reports were recorded on audio and video logfiles.
Study 2. CHALLENGES	Logfiles (CamStudio 2.0)	Participants performed an IPS task as scholar content in the regular classroom at school. During task performances, logfiles were captured. (Analysis of the pre-test)
Study 3. PRE-POST	Logfiles (CamStudio 2.0)	The same participants of Study 2 performed an IPS task as scholar content in the regular classroom at school, two academic years later. During task performances, logfiles were captured. (This study considered the data of the Study 2 –pre-test– and compared it with the new data –post-test)
Study 4. IPS PATTERNS	Logfiles (CamStudio 2.0)	Participants performed an IPS task as scholar content in the regular classroom at school. During task performances, logfiles were captured. (Sub-sample of Study 3)

6.3. Information-problem solving task of each study

The IPS task is the same in each study; however, there are two differences between the studies. One difference is the language –in Study 1, the IPS task was presented and solved in English; in Studies 2, 3, and 4, it is in Catalan. The other difference is the part of the task analysed –in Study 1, we only analyse the first part of the IPS task, so that it is easier to make more understandable the complexity of the analyses and comparison of the information retrieved; whereas in Studies 2, 3, and 4, we analyse the whole IPS task.

6.4. Data analysis procedure of each study

The coding scheme developed for the logfiles data were applied in the four studies. The eye-movements and the cued-retrospective reports only were used in Study 1. Although the four studies are based in the same coding scheme to analyse the logfiles data, **each study has slight particularities in the data analysis procedure**. For instance, Studies 1 and 2 analyse the data in the two levels described in Section 5.1 (first level –more quantitative– and second level –more qualitative), whereas Study 3 is focussed in the first level and Study 4 in the second level. Another example is that Studies 1 and 4 take into consideration both skills and regulation activities whereas Studies 2 and 3 only consider the skills involved in IPS. The particularities of the data analyses procedure will be more widely described in each separate study (Studies 1 to 4, Chapters 5 to 8, respectively).

* * *

Once the research design has been presented, the methodological approach and the techniques selected have been discussed, and each research study has been introduced in terms of participants, methods, techniques, materials and data analyses procedure; we will move into the results of this dissertation. The results are presented through different studies conducted with specific objectives which intend to complement the other study objectives in order to accomplish, altogether, the general purposes of the dissertation –to identify and describe the main challenges of IPS, to study the effect of IPS instruction, and to draw conclusions and educational implications for teachers.

Thus, the following chapter (Chapter 5) presents the first research study, about a comparison of the three different techniques to assess IPS cognitive processes. Afterwards, Chapter 6 includes the second research study, which is focussed in the description of the main challenges that secondary students face while solving an IPS task in their everyday classrooms. Considering those challenges, Chapter 7 presents and analyses the evaluation of an instructional process carried out in secondary classrooms to enhance IPS skills and task performance of students. Finally, Chapter 8 is focussed in the qualitative analyses of the skills, sub-skills and regulation activities performed by those students.

Chapter 5. Unravelling cognitive processes involved in Information-problem solving: logfiles, eye-movements and cued retrospective reports compared (Study 1)

Even though searching information on the World Wide Web (WWW) has become an important activity in education and everyday life, research shows that people have difficulties in doing this efficiently. To tackle this controversy, more insight into the nature and origin of these difficulties is needed. In this study[16] three types of process-tracing techniques were compared to gain insight into the relevant cognitive processes underlying information-problem solving, namely Logfiles (LOG), Eye-movements (EYE), and Cued-Retrospective Reports (CRR). Seventeen participants completed a Web-based information-problem solving task. LOG and EYE were collected *during* and CRR data *after* the tasks performance. Results showed that LOG provided information on overt actions (webpages visited, search terms used, answers given, etc.), which give insight in main cognitive processes involved in information-problem solving, like defining the problem, searching for information, scanning, processing, organising and presenting the found information. However, regulation

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[16] An earlier version of this chapter has been submitted for publication: as Argelagós, E., Brand-Gruwel, S., Harodzka, H., & Pifarré, M. (2012). *Unravelling cognitive processes involved in Information-problem solving: logfiles, eye-movements and cued retrospective reports compared*.

activities are analysed in a more interpretative way and considering the context. EYE-data provided more fine grained insight in these processes, like distinguishing whether participants were reading or scanning a webpage. Moreover, EYE revealed not only on which webpage, but also where on this webpage participants looked. For instance, participants spent the most time reading the assignment (i.e., defining the problem), but the least on navigation icons. CCR, on the other hand, provided more details on the regulation process, like monitoring and steering. These findings are discussed in terms of the kind of information retrieved by each technique. Hence, each process-tracing technique provides a distinctive contribution to understanding information-problem solving.

1. Introduction

Nowadays, searching information on the World Wide Web (WWW) is a key activity in education and everyday life. In particular, in educational settings, students search for information on the Internet to accomplish assignments, even though research revealed that students do encounter difficulties when doing so (Brand-Gruwel et al., 2005; Gerjets & Hellenthal-Schorr, 2008; Walraven et al., 2008). Those difficulties are due to the fact that the access to information with the arrival of the Internet became easy and people are overwhelmed with enormous amounts of information. The difficulty to deal with information on the Internet makes instruction on how to solve information-problems desirable. However, in order to design successful instruction to foster student information-problem solving skills, more insight in the involved cognitive processes is needed.

Research on information-problem solving (IPS) aims at determining the processes involved when people solve complex cognitive tasks in which they have to search, acquire, process, organize and present information. Today, the research focus shifted towards information-problem solving in searching the WWW for information.

To describe the nature of these authentic, everyday problem-solving processes in more depth, researchers analysed thinking-aloud protocols of students who searched the Internet for information (e.g., Gerjets, Kammerer, & Werner, 2011). Other studies included analyses of attentional processes by means of eye-movements (e.g., Jarodzka et al., 2010), or focussed on the actions made on the computer screen to analyse the web-search behaviour of students (e.g., Kuiper et al, 2008). Hence, different measurement techniques can be used to unravel cognitive processes underlying IPS tasks, but the question is what kind of information concerning these processes can be retrieved by different techniques. In this study three different process-tracing techniques will be compared, namely logfiles (LOG), eye-movements (EYE), and cued-retrospective reports (CRR). All of these techniques have shown to successfully unravel cognitive processes underlying task performance without changing the nature of the task (e.g., de Koning et al., 2010; Jarodzka et al., 2010). Furthermore, thinking-aloud is not included, because the comparison between these techniques is already studied by van Gog, Paas, van Merriënboer and Witte (2005).

In the following sub-sections, first, the concept of information-problem solving will be presented. Second, the three techniques to measure the cognitive processes involved in information-problem solving and selected in this study will be described and compared as well as their possible applications in research. Finally, we will formulate the research question that guides our study.

1.1. Searching the WWW described as information-problem solving

As discussed widely in Chapter 2, searching the Web with a specific purpose (in contrast to free surfing) can be described as information-problem solving (IPS; Eisenberg & Berkowitz, 1990; Brand-Gruwel et al, 2005; Moore, 1995; Wolf, Brush & Saye, 2003), which consists of a set of activities required to solve a problem using information from the WWW. Different models state that the IPS process is composed of several sub-skills (i.e., Gerjets & Hellenthal-Schorr, 2008; Marchionini, 1995; Wilson, 1999).

Brand-Gruwel et al. (2005) studied the IPS process of students and distinguished five main skills involved: (1) *Define the problem* to be solved, in order to get a clear insight into it. (2) *Search for information* on the WWW, to select important or interesting sources, to get an overview of the search results, and to judge them. (3) *Scan information*, that is, to judge the information on quality and relevance in order to decide whether or not the information must be linked to the given problem. 4) *Process information*, which is referred to the analysis of the information found in the websites, more in-depth. (5) *Organize and present information*: to give the solution to the problem by means of making the product as required in the task.

In this model, each constituent skill is divided in sub-skills, for instance, during the constituent skill 'Search for information', the following sub-skill can be displayed: 'specify search terms' or 'judge search results'. Furthermore, emphasis is put on regulation activities as orientation (i.e., to make a plan for how to solve the information problem), monitoring-steering (to check if the plan is still the right one, or decide if changes are needed), or testing the process (to evaluate the process followed or the task performance) when solving information-based problems.

1.2. Techniques to measure cognitive skills involved in information-problem solving

Different kind of techniques can be used to measure cognitive processes involved in IPS, such as *observational techniques*, *perceptual process-tracing techniques*, and *reporting techniques*. An expanded description on techniques to measure processes involved in IPS can be found in Chapter 4 (Section 3) in this dissertation.

In this first study, data retrieved from LOG, EYE, and CRR are explored, analysed and compared in order to get insight into the cognitive processes involved in a Web-based problem solving task. The LOG technique provides information on *overt actions* made on the screen during the task, whereas EYE provides unique information on covert skills concerning what is visually attended to, in what order, and for how long. Nevertheless, data retrieved by LOG and EYE require a considerable degree of inferences about underlying cognitive processes, as they do not explain *why* participants execute certain actions or look at certain elements. To capture covert thought skills, CRR is a valid technique.

These three techniques selected for this study –LOG, EYE and CRR– have different features, capture diverse kinds of information and serve different purposes in research and education. In this study we use the three techniques to analyse the same process –an IPS task– and the same participants. Thus, we will be able to compare the data retrieved by each technique. One important reason for the selection of those three techniques is that all of them are able to successfully unravel cognitive processes underlying task performance without interfering with the task (e.g., de Koning et al., 2010; Jarodzka et al., 2010).

1.3. Research question

The main research question addressed is: 'What kind of processes involved in Web-based problem solving can be retrieved using three evaluation techniques – LOG, EYE, and CRR?' We test the following four hypotheses: (1) LOG will retrieve all the actions made during the IPS task performance, that will give insight into the cognitive processes, (2) EYE data will provide information on attentional processes performed during the IPS task, that in turn will give further insight into the cognitive processes, (3) CRR will give more fine grained information about cognitive processes, especially in regulation activities, and (4) the kind of information retrieved by each technique will give a distinctive contribution into the understanding of the processes involved in solving IPS tasks.

2. Method

2.1. Participants

Seventeen PhD students and university staff in the field of the Learning Sciences and Technologies (4 men, 13 women; age M = 36.06, SD = 8.45) participated on a voluntary basis in this study.

2.2. Materials and apparatus

2.2.1. Interest and prior knowledge questionnaires

Participants were engaged to answer five Likert-type items about their interest in astronomy and in the planet Mars, and three open questions about the content of the task –Mars features.

2.2.2. Task

A Web-based task was designed to study participant processes when searching information on the WWW. In this Web-based task, participants were asked to complete a concept map and to collect information about the planet Mars (physical characteristics, orography, atmosphere, climate, satellites). The task was divided in thirteen sub-tasks, for instance ‘diameter of Mars’, ‘Martian year duration’, ‘Climate in Mars’, etc. Figure 11 presents a screenshot of the task, in which thirteen boxes to be filled in can be seen, and three boxes already filled in, that are examples provided by the Web-task for the participants.

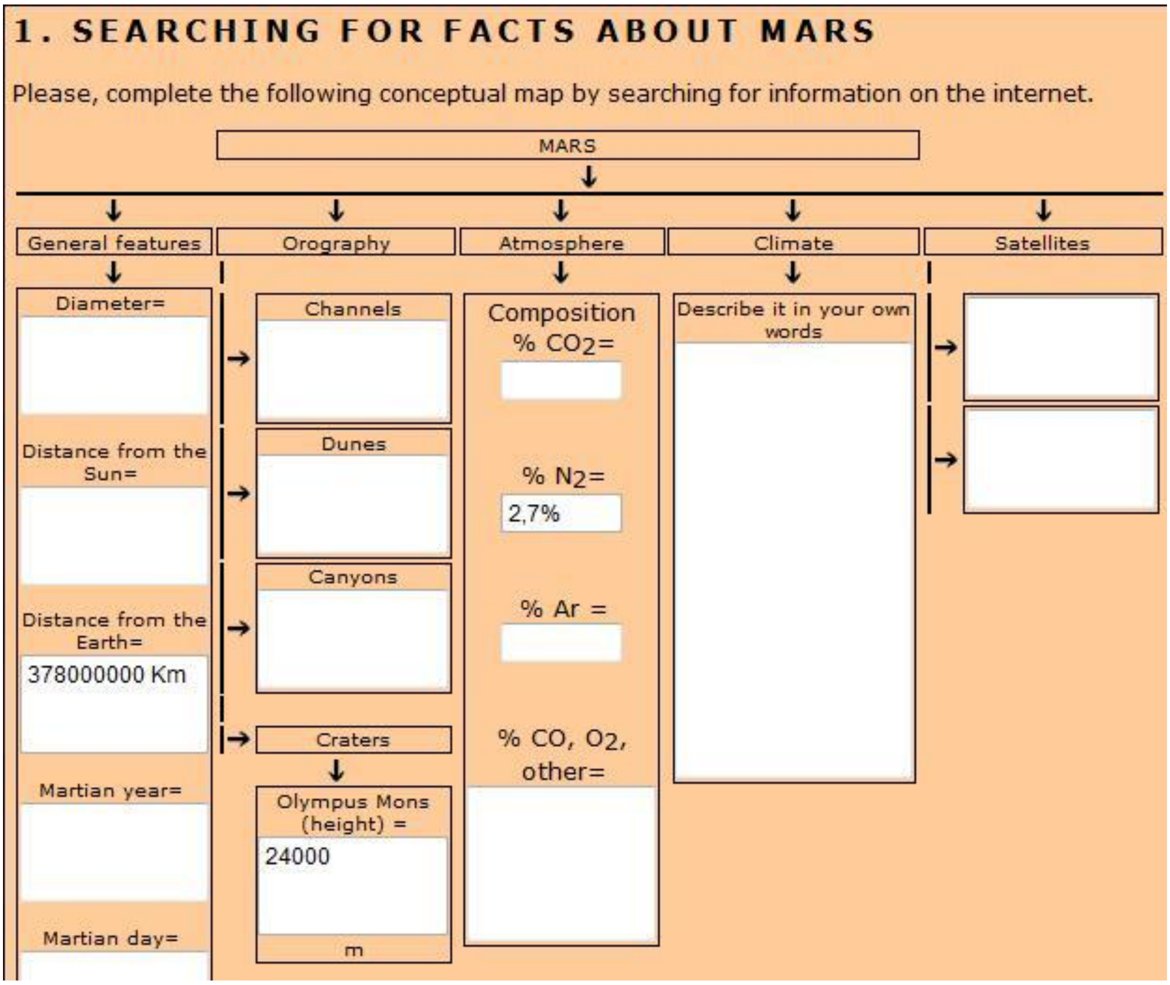


Figure 11. Screenshot of the task

2.2.3. Eye-movement equipment

Eye-movements were recorded with a Tobii 1750 remote eye-tracking system with temporal resolution of 50 Hz, and analysed with Tobii Studio software (www.tobii.com). The verbal data were recorded by the same software using a standard microphone attached to the stimulus PC. Furthermore, this equipment also captured screen recordings of each participant, which were later used for LOG analyses.

2.3. Design and procedure

A within-subject design was used in this study. During individual sessions, participants first filled out a questionnaire about their demographic data, their prior knowledge, and their interest about planet Mars and astronomy. Then they preformed the Web-task for 45 minutes. During task performances, logfiles were captured, and eye-movements were tracked. Afterwards, seven participants randomly selected among the seventeen reported their thoughts while reviewing their overt actions and eye-movements for the first sub-task (logfiles with eye-movements were shown at 75% of the speed). Participants were asked to verbalize everything they were thinking during performing the sub task: “Thinking aloud means that you should really think aloud, that is, verbalize everything that comes to mind, and not mind my presence in doing so, even when curse words come to mind for example, these should also be verbalized. Act as if you were alone, with no one listening, and just keep talking.” When the participants did not verbalize, they were told: ‘Please, keep talking’ (procedure and instruction according to Van Gog, Paas, Van Merriënboer, & Witte, 2005). Their verbal reports were recorded on audio and video logfiles.

2.4. Data analyses procedure

The data obtained during the participants’ task performance were analysed in two different levels, as summarized in Table 14. The first level provided an overview of all the participant IPS processes during the performance of the task (N=17). The second level was an in-depth analysis of seven participant IPS processes during solving the first sub-task. These seven participants were randomly selected. In the following sections we will describe the data analyses procedure for each level and each technique.

Table 14. Analyses per technique and per level

Level	LOG technique	EYE technique	CRR technique
First level analyses: ·17 participants; ·whole task.	·**Constituent skills**: time spent and frequency. ·**Sub-skills**: appropriateness score and efficiency score. ·**Task performance**: correctness ·**Correlations**	·AOI's attention allocation in SERPS and in other web sites. **Time to first fixation**, **Total fixations**, **Number of AOI hits**.	
Second level analyses: ·7 participants; ·1st sub task.	·**Sub-skills**: time spent and frequency. ·**Task performance**: correctness ·**Graphical representation** of participant' web-searching skills	·**Over time analyses** of parameters described in the first level	·**Constituent skills**: frequency. ·**Sub-skills**: frequency. ·**Regulation activities**: frequency.

2.4.1. Logfile technique: First level analyses

As explained in Chapter 4 of this dissertation, data retrieved by LOG technique were transcribed as descriptions of all actions made on the screen by means of mouse or keyboard. As a result, LOG protocols were obtained through this transcription process. Each protocol was coded by the coding scheme presented in Chapter 4 (Section 5.3). Two raters individually scored the 15% of the protocols and interrater reliability was calculated. The similarity between the two raters, expressed in Cohen's Kappa was $k=.94$. Hence, the rest of the protocols were analysed by one rater.

Three types of information retrieved from the LOG were analysed. The first type of information referred to the *constituent skills* performed by each participant: 'Define the problem', 'Search for information', 'Scan and process the information' and 'Organize and present the information'. In order to get insight in the processes, we first calculated the time the participant spent on each skill by counting the total number of seconds invested in each one. Time spent waiting for webpages to load or technical problems was categorised as *waiting time*. In addition, we also counted the number of times each skill occurred. Hence, time spent and frequencies were calculated for each skill.

The second type of LOG information in this level of analyses refers to the following *sub-skills*: search terms typed, correct search terms typed, webpages visited, and webpages used. Furthermore, for each of these measures a correctness score was calculated.

The third type of LOG data in the first level of analyses was the *task performance*. The answers given by each participant were rated with respect to their quality on a rating scale, ranging from 0 points (incorrect), 0.5 points (incomplete), to 1 point (correct). The maximum score that could be obtained in the task was 13 points.

In addition, Pearson's correlation coefficient was used to determine the relationship between the variables described above, with 95% and 99% confidence intervals.

2.4.2. Logfiles technique: Second level analyses

As regards the second level, protocols were analysed more in-depth in order to gain insight in the several processes involved in IPS, only considering the first sub-task performed by each participant. Three types of data were analysed in this level of analyses, as can be seen in Table 14.

The first type of data was the *sub-skills* of each constituent skill. Time spent and frequencies were calculated for each sub-skill performed. The second type of data was the *task performance*: quality of answers given by each participant. The third type of data was the in-depth analyses of the IPS process performed by participants, and was graphically represented.

2.4.3. Eye-movement technique: First level analyses

The first level analyses provided information on the attention allocation across the task webpage, SERPs, and all other webpages visited. The analyses were administered in the following way.

The task webpage was divided into so-called Areas Of Interest (AOIs). The webpage was divided into four types of AOIs: ‘navigation’ (consists of ‘Header & Navigation’ and ‘Save & Continue’), ‘define problem’ (consists of ‘Task description’ and ‘Terms’), ‘define / present information: fact finding’ (consists of ‘Atmosphere’, ‘General features’, and ‘Satellites’), and ‘define / present information: explanation / organization’ (consists of ‘Climate’ and ‘Orography’). For an overview of all AOIs see Figure 12.

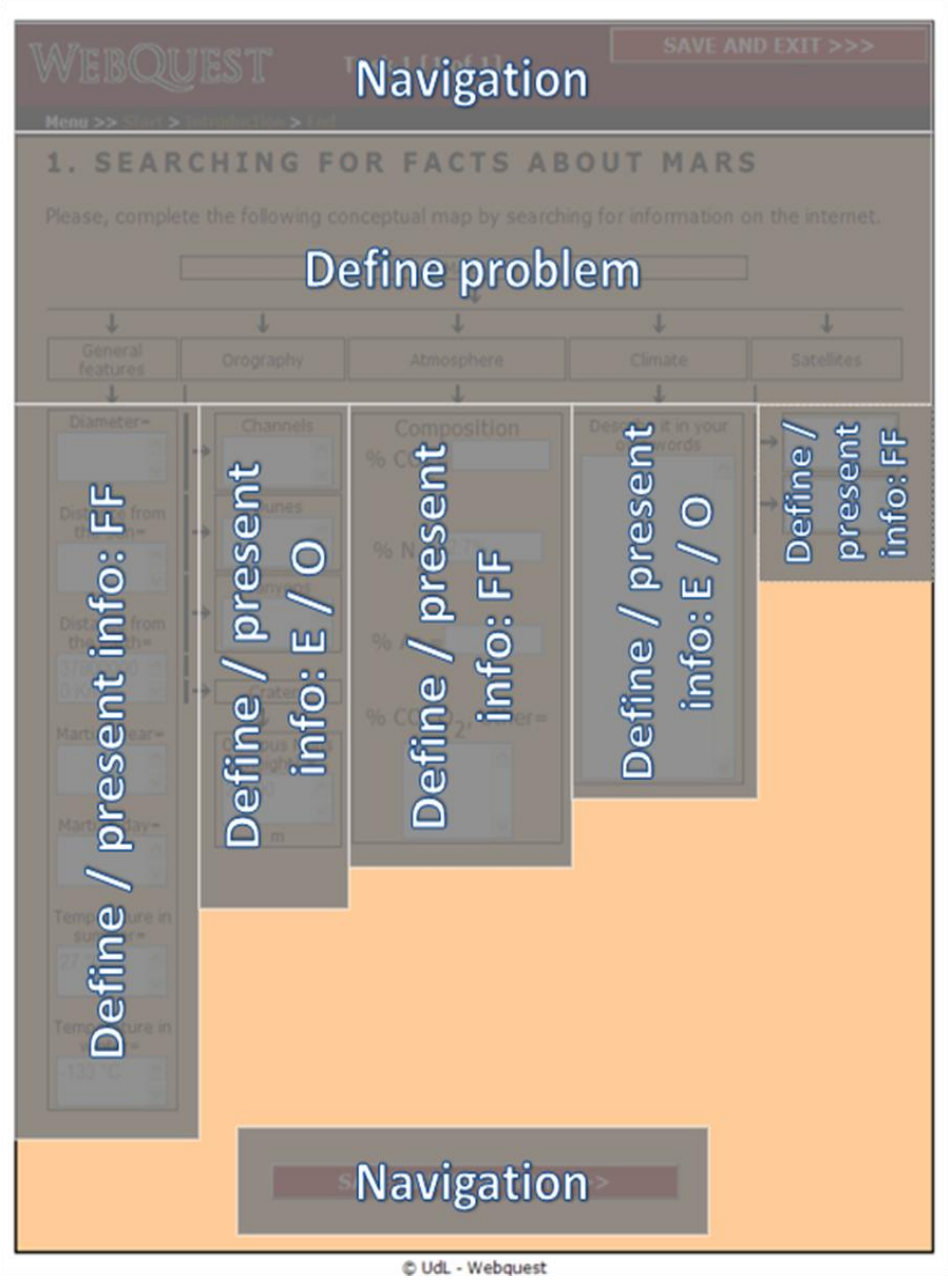


Figure 12. **Spatial division of the task webpage (cf. Figure 11) into four types of AOIs**

The eye-movement parameters that were calculated based on these AOIs are described in the following. *Time to first fixation* is the time from entering the website until the participant fixates on the AOI group for the first time (in seconds) and allows to infer, which AOIs were attended to first and which last. The *total fixation duration* is the duration of all fixations within all AOIs belonging to an AOI group (in seconds) and allows inferring, which AOIs were attended to most. The *number of AOI hits* is the number of times the participant fixated within an AOI group and allows inferring the amount of visual search within an AOI group. The *AOI skip* provides information on how often AOIs or AOI groups were totally skipped.

A fixation was detected by a velocity-based fixation detection algorithm from Tobii (CleraView filter, see www.tobii.com) and the according thresholds were set at 100 ms and 30 pixels (e.g., de Koning et al., 2010; Gerjets et al., 2011).

2.4.4. Eye-movement technique: Second level analyses

For a more detailed analysis of the attentional processes, the eye-movement patterns of seven participants were investigated. In that, total fixation durations were calculated on the task webpage according to the AOIs displayed in Figure 5-2. This time, however, not only summarized in total, but also changing over time. That is, values were calculated anew each time the webpage was re-visited. Furthermore, each webpage consulted in solving the task was investigated separately. In order to compare the different webpages visited, all webpages were divided into an AOI grid of size 10 as shown in Figure 13. Setting AOIs in this way allows inferring to what extend a webpage was consulted. In that, AOI 1 stands for a very superficial processing of the webpage's content. When participants looked only at this AOI, they had only a very superficial impression of a webpage (e.g., only its logo). AOIs 2 represent a less shallow processing, and AOIs 3 a more detailed consulting of the information given on the webpage. AOI 4 covers all parts of a webpage that could be only read when the participant scrolled down. When doing that, participants consulted large parts of a webpage. Hence, visiting this AOI stands for a strong in-depth processing of the information given on this webpage.

Figure 13. Spatial division of all webpage consulted during the task into four types of AOIs: "1" corresponding to the shallowest level of processing and "4" to the deepest level of processing (webpage: http://en.wikipedia.org/wiki/Mars)

2.4.5. Cued-retrospective report technique

With regard to the CRR technique, data (of 7 participants) was only analysed on an in-depth level (i.e., second level of analysis). Data retrieved by CRR were transcribed verbatim. To analyse the protocols, the coding scheme explained in Chapter 4 (Section 5.3.) was used. The scoring system itself consisted of three types of categories. The first category, the constituent skills, was scored in an exclusive way. The second category consisted of the sub-skills of each constituent skill. The third category involved regulation activities (e.g., orientation, monitoring-steering, and testing). All the utterances were coded in each protocol for each participant. Two raters individually scored 15% of the protocols and interrater reliability was calculated. The similarity between the two raters, expressed in Cohen's Kappa was $k = .88$.

After the task performance, the seven participants were asked to verbalize all the things that come to mind while watching the recorded file of their first sub-tasks performed. In that recorded file, participants watched their own actions made in the computer screen as well as their eye-movements; they were the clues to verbalize what they were thinking during the resolution of that sub-task.

3. Results

3.1. Interest and prior knowledge questionnaires

The results on interest did not show differences among the participants for each item 'I'm very interested in astronomy' (*M* = 2.71, *SD* = 1.40), 'I watch movies or documentaries about astronomy very often' (*M* = 2.06, *SD* = 1.39), 'I visit planetariums very often' (*M* = 1.35, *SD* = 0.60), 'I read a lot about astronomy' (*M* = 1.29, *SD* = 0.58), and 'I know a lot about Mars' (*M* = 1.59, *SD* = 0.79).

The participants' answers in the interest questionnaire indicated they have intuitive concepts about the tasks' content and none of the participants showed an extensive knowledge about it. Moreover, none of the questions of the task were answered without searching for information in the Internet. Taking into account these results, in our study the participants' interest and prior knowledge about the content of the task was not a key variable.

3.2. Logfile technique: First level

Time spent on and number of times in each constituent skill by all participants was calculated. The whole task lasted on average 24.56 minutes (*SD* = 4.09 minutes) and consisted on average of 86 constituent skills performed (*SD* = 18.46). The constituent skill in which the group spent the most time and was performed the most often was 'scan and process information'. Figure 14 shows the portion devoted to each constituent skill in terms of time spent and number of times. The difference between the time spent and the number of times gives information about how much time was spent during each time performed, and so it can show a better insight about the process performed by participants. For example, regarding the skill 'scan and process information', the percentage of time spent (57%) performing this skill is higher than the number of times (39%). This means that the time spent in this skill was quite long each time that skill was performed. In contrast, the percentage of time spent on ‘define the problem’ (11%) is lower than the percentage of number of times (25%), therefore, the time spent in each time performed was quite short.

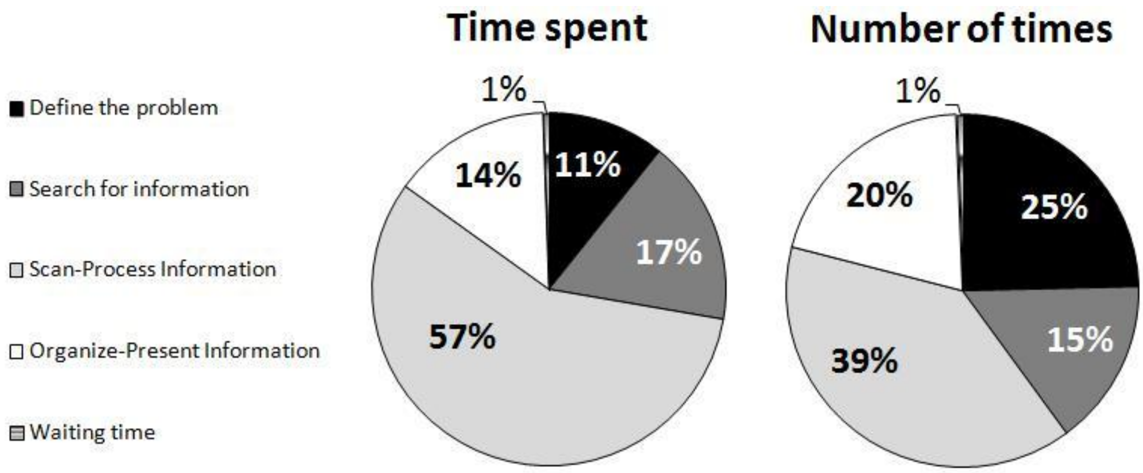


Figure 14. Time spent on and number of times performed each constituent skill

Moreover, the sub-skills search terms typed, webpages visited and used (webpages ‘used’ are the webpages, where the participants retrieved the relevant information from), as well as the task performance (the answers given by each participant) are presented in Table 15. The results are given in an absolute and relative manner.

Table 15. Sub-skills: Search terms typed, webpages visited and used, and task performance per participant, in absolute and relative fashion

	Search terms typed (ST)			Websites visited and used			Task performance: Answers given (AG)		
	ST	Correct ST	**% SEARCH TERMS CORRECTNESS**	Webs visited	Webs used	**% WEB USE EFFICIENCY**	AG	Correct AG	**% ANSWERS GIVEN CORRECTNESS**
M	**8.76**	**8.29**	**94.10**	**13.71**	**5.29**	**49.61**	**10.94**	**10.12**	**72.27**
SD	**5.01**	**4.87**	**9.78**	**7.39**	**3.08**	**28.15**	**1.60**	**2.20**	**15.75**

A correlation analysis revealed substantial correlations between ‘number of ST’ and ‘number of correct ST’ (r = 0.98, p < .01), and ‘number of Websites visited’ (r = 0.74, p < .01), and ‘number of Websites used’ (r = 0.80, p < .01). In addition, the ‘number of correct ST’ also correlated with ‘number of Websites visited’ (r = 0.72, p < .01), and with ‘number of Websites used’ (r = 0.80, p < .01). On the other hand, correlations also were found between ‘number of AG’ and ‘number of correct AG’ (r = 0.51, p < .05). However, ST or Website visited or used did not correlate with AG.

3.2. Logfile technique: Second level

This second level of analysis is an in-depth analysis, in which all the actions performed by the participants are taken into account. Information about each sub-skill that belongs to each constituent skill is retrieved. This analysis was made for seven participants during their first sub-task performed. Table 16 shows the time spent and the amount of times each sub-skill was performed by the seven participants.

Table 16. Sub-skills performed the seven participants: time spent (in minutes) and number of times

		Time spent		Number of times	
Constituent skills	Sub-skills	M	SD	M	SD
Define the problem	Analyses of the Demand (AD)	0:22	0:09	2.00	0.70
	Consulting of the Demand (CD)	0:12	0:09	3.29	1.05
Search for Information	Web Address Typing (WAT)	0:01	0:02	0.14	0.06
	Search Terms Typing (STT)	0:18	0:16	2.29	0.93
	Select a Result (SR)	0:19	0:14	2.86	1.17
Scan and Process Inf.	Look at the Web Page (LWP)	0:53	1:16	5.43	2.21
	SCAN-SCroll (SCAN-SC)	0:13	0:15	2.43	0.99
	Look at an IMAGE (IMAGE)	0:01	0:02	0.29	0.12
Organize and Present Inf.	Objective Answers (OA)	0:03	0:04	1.29	0.52
	Explanation Answers (EA)	0:02	0:06	0.29	0.12
Other actions	Adjust the Page (AP)	0:03	0:04	1.14	0.47
	Select a Link (SL)	0:02	0:05	0.57	0.23
	Click (CK)	0:22	0:06	9.86	4.02
	Technical Aspects (TA)	0:04	0:07	0.57	0.23
	Waiting Time (WT)	0:03	0:01	0.14	0.06
	Total	2:59	3:06	33.00	13.00

This level of analysis provided extra information, in comparison with the first level, because it goes a level deeper. For example: it can be seen whether the participant analysed the demand before searching or consulting it while searching (regarding the constituent skill ‘Define the problem’), or how long and how many times the participant typed search terms or selected a results (regarding the constituent skill ‘Search for information’).

LOG file analysis can also be a good contribution in order to have a representation related with the sequence in which participants execute the different IPS skills. Figure 5-5 illustrates the path followed by one participant, Yvonne (the name is not real), in her first sub-tasks. The number in the graphic indicates the order in which the skills were performed. In this case, the first action performed by Yvonne was ‘define the problem’. Next, she searched for information and used the search terms *mars*. After that, the participant accessed a webpage to process the information. In a certain moment, she consulted the demand and went back to the webpage. At the end, she answered the sub-task by typing a correct explanation answer about *channels of mars*. This sub-task lasted 3:47 minutes, and required 16 sub-skills or actions. According to Figure 15, those 16 actions are summarized in 5 constituent skills.

This representation gives valuable information and a better understanding about the IPS skills performed by participants. Furthermore, this representation allows comparison among participants about which path can be more efficient to solve the task correctly.

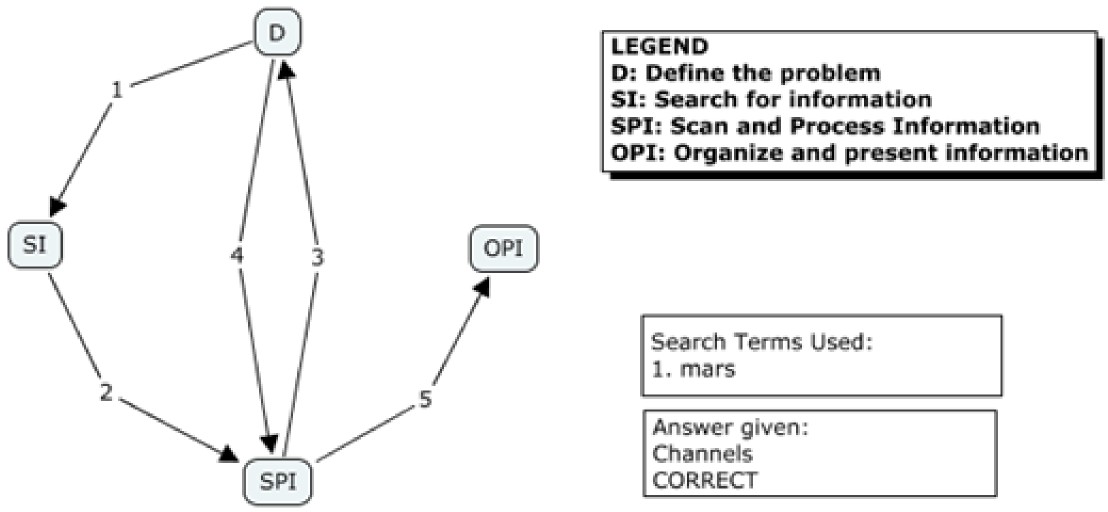


Figure 15. Graphical representation of the first sub-task performed by Yvonne

3.3. Eye-movement technique: First level

Concerning the mean time to first fixation, participants looked first at the AOI ‘define / present information: fact finding’ (5.36 sec, *SD* = 6.31). Then they fixed at ‘define / present information: explanation / organization’ (13.12 sec, *SD* = 27.03), then at ‘navigation’ (28.41 sec, *SD* = 80.05), and last at ‘define problem’ (43.60 sec, *SD* = 177.86). In terms of total fixation duration, participants looked the longest on ‘define / present information: fact finding’ (76.06 sec, *SD* = 39.56), then on ‘define / present information: explanation / organization’ (62.54 sec, *SD* = 55.13), shorter on ‘define problem’ (24.51 sec, *SD* = 12.75), and the shortest on ‘navigation’ (3.27 sec, *SD* = 3.28). In terms of AOI hits, participants made most fixations on ‘define / present information: fact finding’ (295.00, *SD* = 134.07), almost the same on ‘define / present information: explanation / organization’ (234.29, *SD* = 211.89), less fixations on ‘define problem’ (96.53, *SD* = 39.60), and least fixations on ‘navigation’ (13.94, *SD* = 3.28). In terms of AOI skip, no AOI group was skipped, however, within the AOI group ‘navigation’ single AOIs were skipped most often (4 times) and within the AOI group ‘define / present information: fact finding’ single AOIs were skipped twice. Besides that, no AOIs were skipped.

3.4. Eye-movement technique: Second level

Figure 5-6 shows the viewing pattern over time for Yvonne in the first sub-task. The task webpage (i.e., the webpage in which the participant defines the problem and organizes-presents the information) is indicated as pattern columns, while all other consulted webpages (i.e., webpages in which the participant searches for information and scans-processes the information) are shown in grey-colours. One column corresponds to one singular visit of a given webpage and hence, the amount of fixation duration is given in a percentage value.

As can be seen from the legend, participant 10 only attended to these areas in the beginning of executing this sub-task. Her or his amount of attending to the “define problem” AOIs varies across the task flow. The viewing pattern is clearly dominated by attention towards “defining / presenting information: explanation / organization”. For all other webpages the amount of darkness is related to the level of processing the webpage: the darker the column, the more in depth the webpage was processed, the lighter the column, the shallower the webpage was processed. From the diagram it can clearly be seen, how this viewing pattern varies over time.

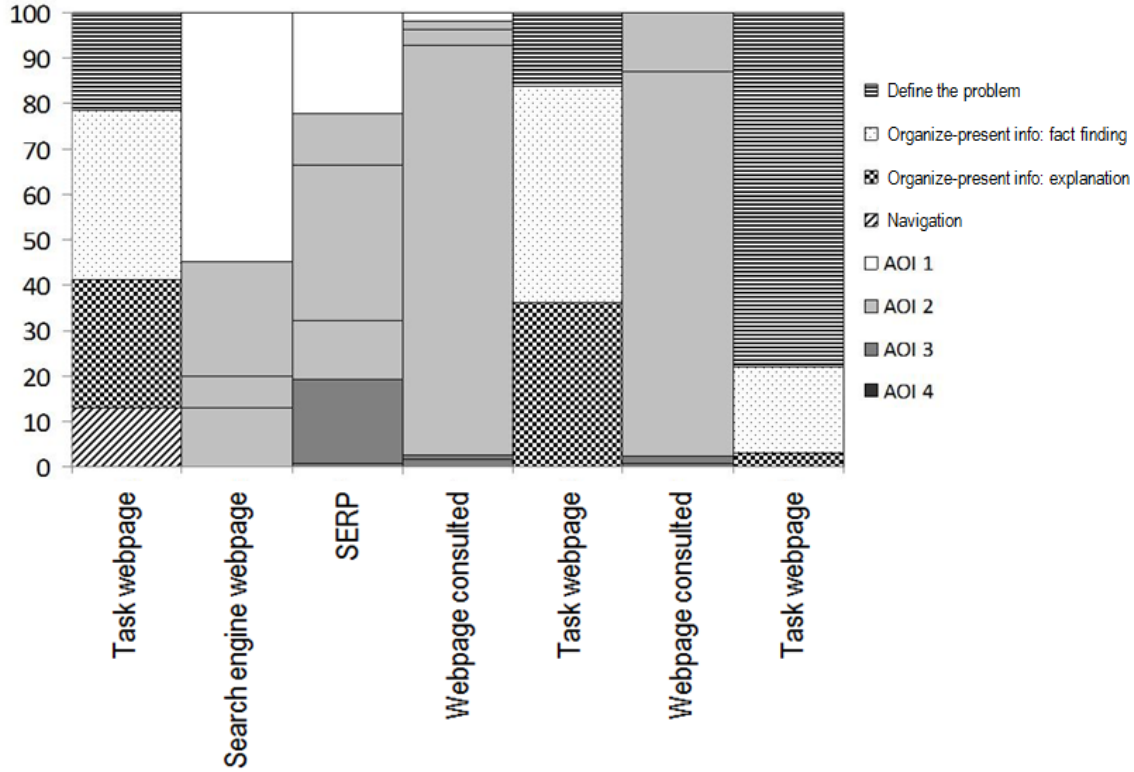


Figure 16. Viewing pattern over time for Yvonne in her first sub-task

In addition, Figure 17 depicts the order in which the participant approached this sub-task across time. During the first visit, this participant first looked at the 'define problem' area, then at the 'define / present information' area and back to the 'define problem' area. Next, she looked back and forth in the 'define / present information' areas, ending in the 'navigation' area. During her second visit, Yvonne started at the 'define / present information' area and then going to the 'define problem' area. During the third visit, this participant started in the 'define / present information' areas, going then to the 'define problem' area and back to the 'define / present information' area.

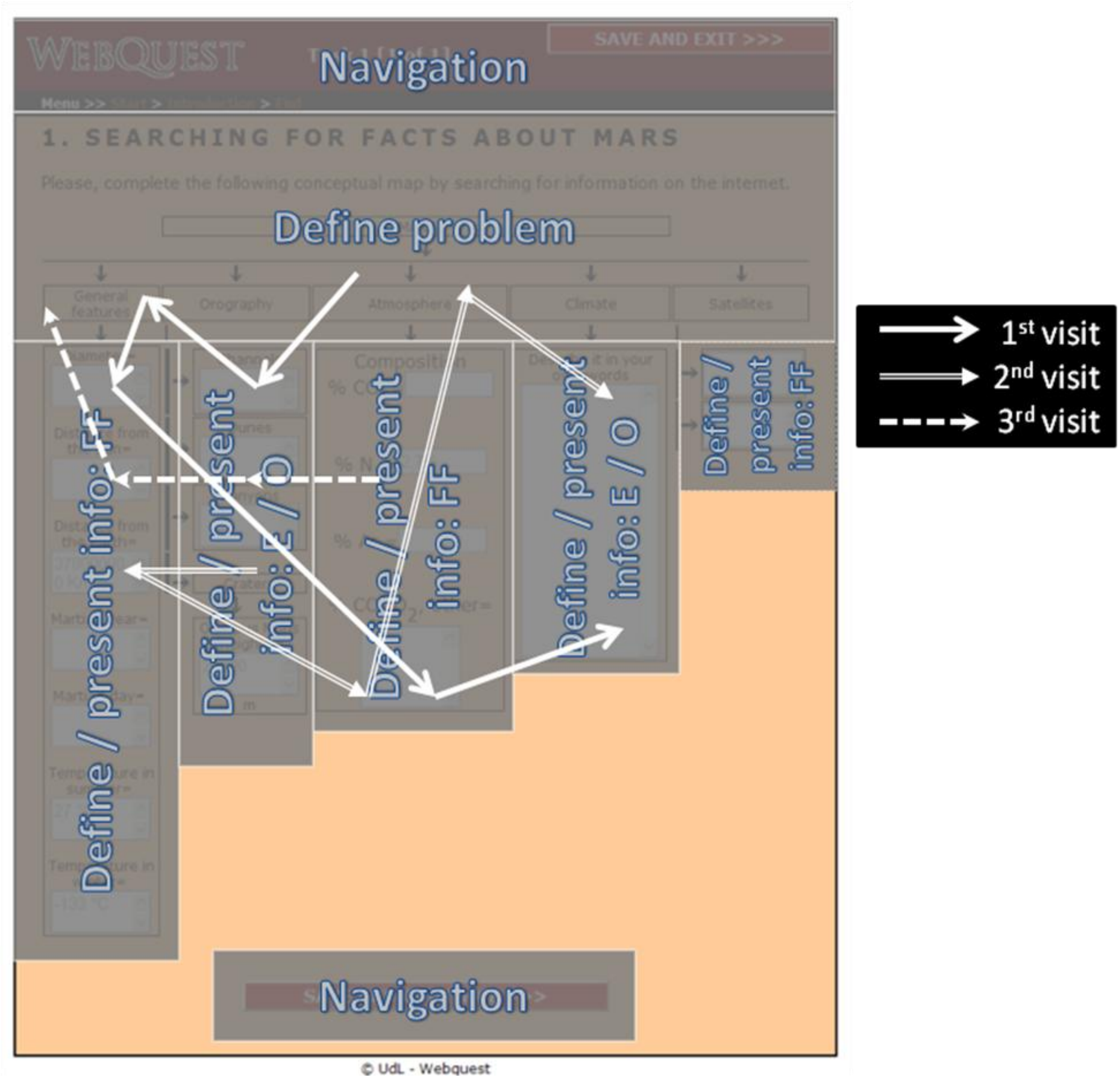


Figure 17. Viewing order over time for Yvonne in her first sub-task

3.5. Cued-retrospective reports

Regarding this technique, only the second level of analyses was performed, because this type of analysis is characterized as an in-depth analysis. In this section, the number of utterances each participant gave is presented. Tables 17 and 18 show the utterances referred to the constituent skills and sub-skills, respectively. In addition, Tables 19 and 20 present the ones referring to the regulation activities.

Table 17. Constituent skills: number of utterances given in the participants' first sub-tasks

	Define the Problem	Search for Information	Scan-Process Information	Organize-Present Information	TOTAL
M	5.00	6.14	10.14	1.71	23.00
SD	2.57	2.98	5.59	1.31	8.57

Table 18. Sub-skills: number of utterances given in the participants' first sub-tasks

		Num. of utterances	
Constituent skills	Sub-skills	M	SD
Define the problem	Analyses of the Demand (AD)	0.86	0.90
	AD-Reading (AD-READ)	0.86	1.21
	AD-Information Needed (AD-NEED)	1.29	1.11
	AD-Formulating questions (AD-QUEST)	0.14	0.38
	AD-Activating prior knowledge (AD-PRIOR)	0.14	0.38
	AD-About the product (AD-PROD)	0.00	0.00
	Consulting of the Demand (CD)	0.29	0.49
	CD- Reading (CD-READ)	0.14	0.38
	CD- Information Needed (CD-NEED)	0.71	1.25
	CD- Formulation of questions (CD-QUEST)	0.29	0.76
	CD- Activating prior knowledge (CD-PRIOR)	0.14	0.38
	CD- About the product (CD-PROD)	0.00	0.00
Search for Information	Web Address Typing (WAT)	1.43	2.70
	Search Engine Choosing (SEC)	0.14	0.38
	Search Terms Typing (STT)	1.29	1.80
	Search-engine Options Use (SOU)	0.14	0.38
	Select a Result – Assessing by Usability (SR-A-U)	0.14	0.38
	Select a Result – Assessing by Reliability (SR-A-R)	1.14	2.19
	Select a Result – Assessing by U & R (SR-A-UR)	0.00	0.00
	Select a Result – Assessing no specifying (SR-A)	1.14	1.86
Scan and Process Inf.	Look at the Web Page (LWP)	0.57	1.13
	SCAN-SCroll (SCAN-SC)	0.43	0.79
	SCAN-Follow Words (SCAN-FW)	0.29	0.49
	READ-Follow Sentences (READ-FS)	0.86	1.21
	Look at an IMAGE (IMAGE)	0.29	0.76
	Scan-elaborating on the content (SCAN-ELAB	1.43	2.15
	Read-elaborating on the content (READ-ELAB)	1.57	1.81
	Assessing WebSite by Usability (AWS-U)	2.57	3.99
	Assessing WebSite by Reliability (AWS-R)	0.00	0.00
	Assessing WebSite by U & R (AWS-UR)	0.00	0.00
	Assessing WebSite no specifying (AWS-A)	0.14	0.38
Organize and Present Inf.	Objective Answers (OA)	0.86	0.69
	Explanation Answers (EA)	0.29	0.49
	Reformulating sentences while typing (EA-FORM)	0.00	0.00
	Elaborating on the content while typing (EA-ELAB)	0.00	0.00
	Elaborating on structure while typing (EA-STRUC)	0.00	0.00

Other actions	Adjust the Page (AP)	0.57	1.13
	Select a Link (SL)	0.14	0.38
	Click (CK)	0.43	0.53
	Technical Aspects (TA)	1.43	1.62
	Waiting Time (WT)	0.29	0.49
	Total	**22.43**	**11.91**

Table 19. Regulation activities (more detailed): number of utterances given in the participants' first sub-tasks

	Number of utterances	
Regulation activities	M	SD
Orientation	2.43	1.86
Monitoring-Steering	14.43	15.43
Testing	1.43	0.71
Total	**18.29**	**11.35**

Table 20. Regulation activities (more detailed): number of utterances given in the participants' first sub-tasks

		Number of utterances	
Regulation activities		M	SD
Orientation	Orientation on the task (O-TASK)	1.57	1.90
	Orientation on the time (O-TIME)	0.86	1.21
MS	Monitoring-Steering	14.43	8.85
Testing	Testing the size (T-SIZE)	0.14	0.38
	Testing the quality (T-QUAL)	0.57	0.79
	Testing the style (T-STYL)	0.43	0.53
	Testing the completeness (T-COMP)	0.14	0.38
	Testing whether there are overlap ideas (T-OVER)	0.14	0.38
	Total	**18.29**	**11.35**

Furthermore, it is interesting to see that the utterances given by the participants can be grouped in several categories, such as utterances about overt actions, about attentional processes, about cognitive processes (considering constituent skills and sub-skills), and finally about regulation activities. The average utterances given by the participants submitted to cued retrospective reports of this study were 17%, 10%, 29% and 44% respectively.

3.6. Linking the results obtained by the three techniques

The main purpose of this study was to know what kind of cognitive processes involved in information-problem solving can be retrieved using the three evaluation techniques –LOG, EYE and CRR. We have distinguished two levels of analyses: first level (17 participants, all the task analysed) and second level (7 participants, one sub-task analyzed). In this section we present a comparison between the data retrieved by the three different techniques.

The results reveal that the kind of information retrieved by each technique can give a distinctive contribution into the understanding of the IPS task as can be seen in the example of the Figure 18. In the middle of this figure, the square contains the graphical representation of the path followed by the participant Yvonne during her first sub-task (cf. Figure 15), which consists in the different constituent skills. In Figure 18, the 1st arrow focuses on the first time Yvonne defines the problem (D), the 2nd is referring to search for information (SI), the 3rd concerns scanning and processing information (SPI), and the 4th is about organizing and presenting the information (OPI). The contribution of each technique –LOG, EYE, and CRR– can be appreciated in each zoomed picture. For instance, the first constituent skills performed (define the problem) is presented in detail, and shows that: LOG provided the information of the time spent during the action of 'analyses of the demand'; EYE offered the information of the viewing order over time and the time spent in each AOI during the performance of that constituent skill; and CRR provided the utterances given by the participant concerning the sub-skills performed during that consituent skill (define the problem).

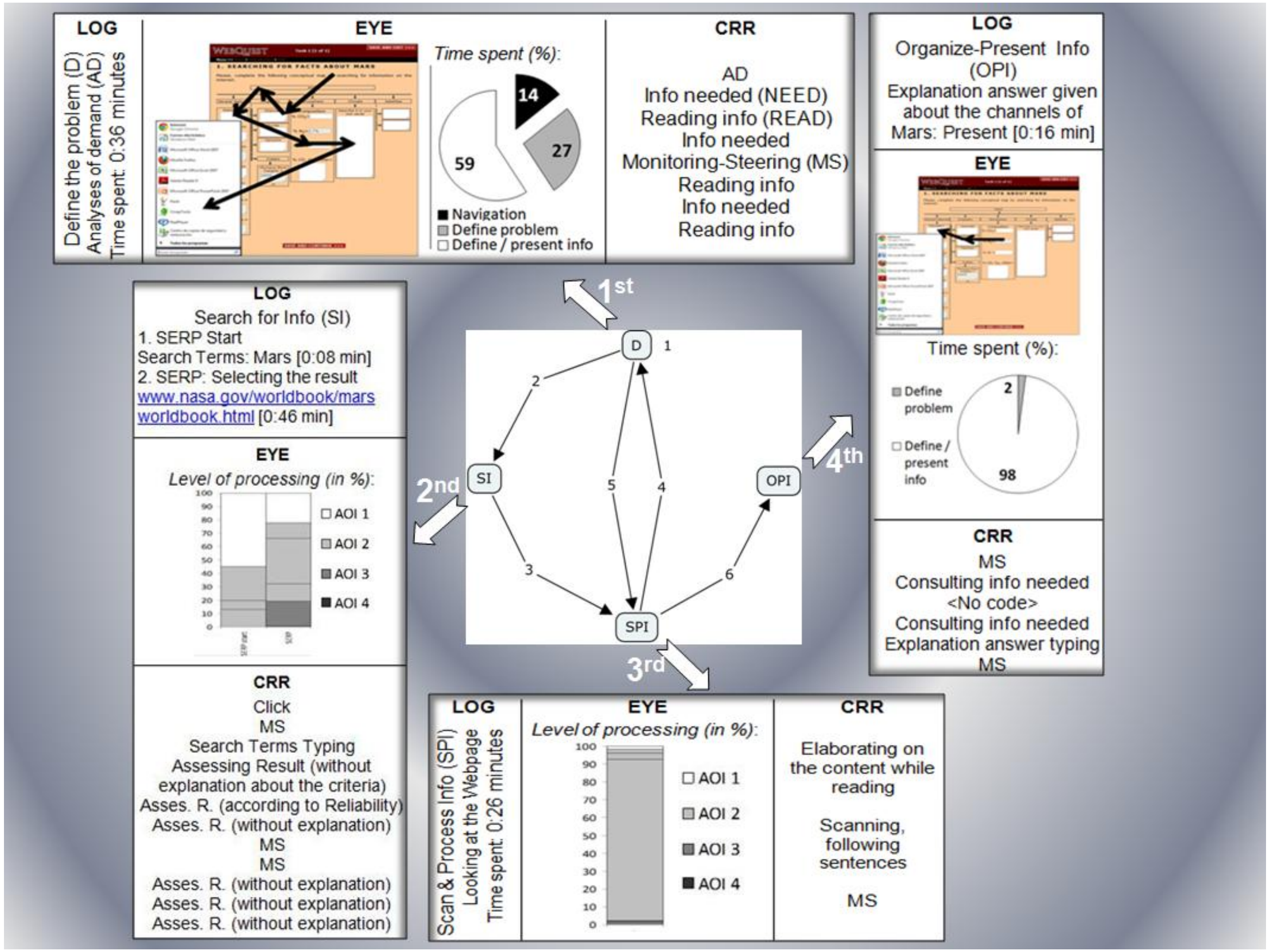


Figure 18. Combination of the information retrieved by each technique (example: Yvonne's sub-task)

4. Discussion and conclusion

The main research question that led our study was the following one: 'What kind of cognitive processes involved in information problem solving can be retrieved using the three evaluation techniques –LOG, EYE, and CRR?'. In this section, we will discuss each technique and give a conclusion about the distinctive contribution that each technique can provide into the understanding of the IPS processes. Besides, we will highlight some points to be considered about each technique regarding further research or instructional design.

Concerning the data that can be retrieved, LOG collects all the overt actions made in the computer screen, which give insight about cognitive processes (constituent skills and sub-skills), while EYE collects the attentional processes, which give more fine grained information about the areas which were paid attention to, and so they also give insight about cognitive processes. Finally, CRR collects utterances on cognitive processes and regulation activities. It is important to highlight that whereas LOG can retrieve all the actions made in the computer screen and EYE is able to retrieve all the attentional processes performed, CRR cannot retrieve all the actions, attentional processes performed, cognitive processes (including both skills and sub-skills) or regulation activities, as explained bellow as a limitation. Figure 19 gives an overview of the kind of information obtained by each evaluation technique in this study.

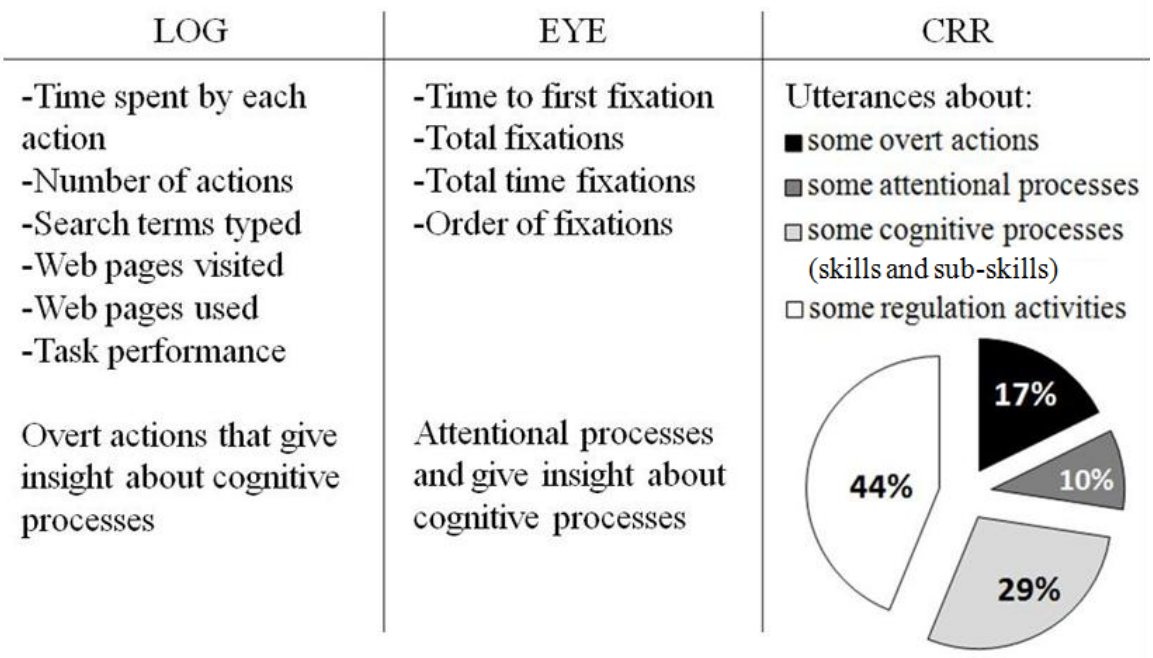


Figure 19. Information retrieved by each technique

To illustrate in which manner each technique contributes to the analyses of an IPS task, and under which conditions each could be used, we present the following examples. LOG would be a good option to assess the searching strategies of students working at their natural environment with authentic tasks (i.e., learning curricular contents using the Internet in their classroom). However, if we need to examine the depth of reading processing a webpage while searching, EYE data could give us better evidences. Following the same example, when the aim is to understand the regulation activities involved in the resolution of the web-search task, CRR would be the best option. Another example could be the selection of the results from a SERP. Using LOG technique, we know which result was selected and how much time was spent by each participant in doing so. Using EYE, we can see if the web-searcher paid attention to the title, or the description, or the URL of the result selected or discarded. Finally, using CRR technique, we could know whether the web-searcher evaluated the results according their usability, their reliability, or both. So, it depends on what we want to retrieve and the leading research questions.

This study also gives insight in the limitations of each technique that should be considered when preparing a study. Regarding the LOG technique, the main limitation found in this study was the risk to over interpret the actions made by the participants. As this instrument only captures the actions made on the screen, some actions can easily be misinterpreted. For instance, LOG does not notice the periods of time when the participant is not looking at the computer screen. Another limitation was the time required to code each video file of each participant and to code the assumed actions into the different skills. In order to facilitate this detailed and lengthy task, software to obtain ‘event log files’ (or lists of each action made in the computer: clicks, webpages open, search terms typed, URLs open, the time spent in each event, etc.) is available, however not for free. For instance, Meta-Analyzer (Hwang, Tsai, Tsai, & Tseng, 2008), NCSA’s XMosaic (used in the study of Catledge & Pitkow, 1995), Morae Manager (used in the study of Deursen, 2010), or Wayang Outpost (used in the study of Arroyo and Woolf, 2005), among others.

Regarding the EYE technique, researchers should take the size of the defined AOIs into account when comparing among them, because this may influence the probability to look at them. In addition, it is necessary to consider the constituent skills involved when looking at each AOI, otherwise the researcher cannot distinguish which skill has been performed. For example, in this study, the designed Web-based task required the participants to perform two different constituent skills –namely: ‘define the problem’ and ‘organise and present the information’– while looking at the same AOI. Therefore, it was difficult to code the data regarding these two different constituent skills during the EYE data analyses. In order to avoid this kind of problem, researchers should consider this issue while designing the Web-based task that will be used in the study and be aware that in each AOI a unique constituent skill could be performed.

Regarding CRR, it showed that some utterances were not possible to code because, first, participants did not give enough information about the processes performed (i.e., ‘I don’t remember what I was doing here’); second, some participant utterances were quite subjective (i.e., ‘I think I was thinking...’); third, sometimes participants were not able to explain (verbalize) what processes they performed and they could not give any utterance; fourth, although the number of times participants performed a constituent skill can be retrieved, the time spent performing each of them cannot be calculated. Therefore, as suggested by van Gog et al. (2009), an accurate selection of the task is needed, in order to assure it is short enough to be successfully evaluated using CRR. Besides, an adequate training for the participants is also necessary to be able to verbalize their thought as much as possible.

To conclude, the analyses of the three techniques in this first study of our dissertation, let us to affirm that the different features of each technique and the distinct kind of information that each one can retrieve, are critical factors in deciding which evaluation technique to use in a research study. In addition, the situational circumstances and the evaluation goals or research questions also should be considered to choose one or another technique. From our perspective, apart from choosing one or another technique, it would be even more interesting to combine them and triangulate the information retrieved by each technique, due to the fact that each one can give a distinctive contribution into the better understanding of the IPS process, as we attempted in Figure 5-8. In addition, richer *learner profiles* can be constructed by the triangulation of information retrieved by each technique, and these learner profiles may lead to drawing educational implications and conclusions on instructional design.

In this study, we compared and analysed the data obtained by three techniques while the participants performed an IPS task. In our view, the conclusions drawn in this study can be generalised to the analyses of cognitive processes involved in other kinds of tasks or environments, such as collaborative learning, peer-to-peer interaction, self-regulation learning, game-based learning, or others.

* * *

Considering, on the one hand, the conclusions extracted from this first study (in particular the idiosyncratic affordances and limitations of each technique) and, on the other hand, the circumstances and conditions of the following studies (IPS tasks in classrooms settings), the technique used in them will be the logfiles. Thus, the next study (Chapter 6) pretends to identify and describe the main challenges that secondary students face while using the Internet while learning curricular contents at school. The other two following studies (presented in Chapters 7 and 8) have the purpose of comparing IPS processes of students who received or not IPS instruction at school, in more quantitative and qualitative ways, respectively.

Chapter 6. Secondary student challenges in Information-problem solving: some clues for the design of efficient instruction (Study 2)

After examining three different techniques to assess the IPS processes in the first study of this dissertation, we will adopt one of these techniques (logfiles) to retrieve and analyse valuable information in order to continue our research about the IPS cognitive processes of students. In this second study[17], the main goals are related with the analysis of the challenges that secondary students face when solving Web information-problem tasks at school, as well as the relationship between the variables involved in the process followed to solve a problem using Web information. Forty secondary students, who were not given any previous IPS instruction, solved a science task using Web information in their regular classrooms. The students' actions on the computer screen were logged. Quantitative and qualitative detailed analyses showed specific challenges when (1) typing appropriate search terms, and when (2) selecting results from a 'search engine results page' (SERP), which hinders the process of solving digital tasks. In addition, the participants had a lack of quality in the product obtained as a resolution of the problem, and a high correlation was found between the process and product, as well as between the process variables. Furthermore, these findings contribute to the discussion of how well-designed and well-embedded scaffolds could be designed in

[17] An earlier version of this chapter has been submitted for publication as: Argelagós, E., & Pifarré, M. (2012). *Secondary student challenges in Information-problem solving: some clues for the design of efficient instruction.*

instructional programs in order to promote the development of the students' digital competences that may lead them to a better use of Web information and to an effective resolution of information problems.

1. Introduction

As introduced in previous chapters of this dissertation, students in secondary education use the Internet for both leisure and school assignments; however, the fact is widely accepted that the complex cognitive activities involved in the skills of gathering and processing information from the Web are not instinctively acquired (Wood, 2009). Therefore, students have serious difficulties in such skills (Walraven et al., 2008) and different educational researchers demand more attention in studying the nature of these challenges, giving more clues about how well-designed and well-embedded scaffolds could be designed in instructional programs, so that students can develop IPS skills to overcome these challenges (e.g., Raes et al., 2011). This second study falls in this line of research and the main goals of this study are (1) to give insight about the challenges that secondary students face when solving information-problem tasks in their everyday classrooms, and (2) to analyse the relationship between the variables involved in the process followed to solve a problem using Web information, and the product obtained as a resolution of the problem. These results will illuminate us to draw educational implications about the intervention needed by students in order to promote the development of effective IPS skills.

In the following sub-sections, first we will summarize the concept of the information-problem solving process. Next, we will analyse the students' difficulties in developing effective skills in solving information-problems. Finally, we will formulate the objectives that guided this second research study.

1.1. Information-problem solving

As expanded in Chapter 2, the IPS process has been defined as the process that involves complex cognitive activities to solve a problem using Web information (Eisenberg & Berkowitz, 1990; Brand-Gruwel et al., 2005). The IPS process can be segmented into several skills: (1) An information-problem is defined. (2) A search engine (i.e., Google) is usually selected, where a query with search terms is entered. Consequently, a 'search engine result page' (SERP) with a list of search result links is displayed to the user. (3) Those search results are assessed by checking the information that each result contains: i, e., title, summary, and 'uniform resource locators' (URL). (4) After accessing a selected webpage, its information is scanned, evaluated, and extracted for further processing in case of relevant information. (5) The information from different webpages is integrated in order to solve the problem. Each skill is decomposed into several sub-skills. For instance, the skill 'search for information' is constituted by the sub-skills 'specify search terms' and 'judge results from a SERP', as was proposed by Brand-Gruwel et al. (2005) in their IPS model.

Several studies have reported that users of all ages, and especially teenagers, struggle in the development of IPS skills. In the next sub-section, we will review those challenges, and for this revision we will follow the skill decomposition model proposed by Brand-Gruwel et al. (2005).

1.2. Challenges that secondary students face in information-problem solving tasks

In this sub-section, we review the challenges that secondary students usually face while solving information-problems. We divide this review in two main parts: challenges related to the IPS process (constituent skills and sub-skills), and difficulties to write a good product[18].

1.2.1. Process

As regards the constituent skill 'defining the problem', teenagers have difficulties with 'formulating questions' (Wallace et al., 2000), 'activating prior knowledge', 'clarifying task requirements' and 'determining needed information' (Walraven et al, 2008). Most teenagers start searching immediately without exploring the topic, planning the search or thinking about the task (Fidel et al., 1999).

[18] For a wider review, consult Chapter 2 (Section 3).

In relation to the constituent skill 'searching for information', secondary students do not always know what 'search terms' to use (MaKinster et al., 2002; Wallace et al., 2000). Most of the times, students do a free search when they navigate the hypermedia environment, as opposed to having specific learning goals (Azevedo et al., 2004). Furthermore, 'judging the search results' is not done systematically. Students have difficulties to open websites based on a valid judgement of the results. The source is not always questioned and the choice to open a site is mostly guided by the title or summary of the site. Without any preparatory work on searching objectives, students tend to select websites that seem relevant based on superficial cues (Rouet et al., 2011).

To 'scan information', teenagers also demonstrated problems in separating reputable and questionable materials, and selecting and judging information (Lorenzen, 2002). They use information that could answer their question, even if the site was from a commercial source and not intended for science assignments (Fidel et al., 1999).

Concerning the constituent skill 'processing information', expert searchers spend more time on elaborating the content than novices (Brand-Gruwel et al., 2005). In the same line, Goldman (2011) found that a difference between better and poorer learners was the amount of time spent on a site: better learners spent more time on reliable than unreliable sites and poorer learners did not differentiate them. Other studies also highlighted the students' difficulties to find relevant and reliable information from printed or Web-based documents (i.e., Britt & Aglinskas, 2002).

Finally, to 'organize and present information', students predominantly use ineffective strategies such as copying information from the hypermedia environment to their notes (Azevedo et al. 2004). Raes et al. (2011) also observed that students tend to reduce the whole task to find an obvious answer on a particular website while less attention was paid to understand the content and critical thinking.

It can be concluded, then, that secondary students face serious challenges during the IPS process. This fact requires educational implications about the intervention needed at schools in order to help students to develop effective IPS skills and sub-skills.

1.2.2. Product

The product obtained in an IPS task can be outlined as a writing essay or as a set of answers to specific questions (Jonassen & Kim, 2009), among other forms. In the literature, this type of product has also been called 'task performance'. This product is the result of the process followed solving the information-problem that was presented at the beginning of the task. When the product is presented as an essay, this shows (1) the content understanding, and (2) the argumentation developed by the 'solver' through the IPS task.

(1) **Content understanding** is not only a recollection of facts and definitions associated with a particular subject area, but it can be viewed as a matter of degree in which an individual understands concepts, principles, structures, or processes at a relatively deep level and is able to demonstrate certain behaviours (Nickerson, 1995). Therefore, understandings could be made evident to others in terms of overt behaviours as learners communicate or act in three ways (Perkins, Schwartz, West, & Wiske, 1995; Hakkarainen, 2003):

1. *Offering explanations*. Learners display this kind of understanding by giving examples, highlighting critical features, and responding to new situations, whereas learners who simply present facts and describe phenomena without the ability to explain concepts clearly lack understanding.
2. *Articulating richly relational knowledge*. Learners express this kind of understanding with explanations that link to related aspects of a concept or phenomena.
3. *Displaying a revisable and extensible Web of explanation*. Learners demonstrate this kind of understanding by revising and extending explanations beyond the original source of information to new contexts or situations.

Furthermore, another approach to the writing processes made a distinction between *knowledge telling* and *knowledge transforming* strategies (Scardamalia & Bereiter, 1991). In a similar vein, Priemer and Ploog (2007) identified two types of students with respect to the ways they used information obtained from the Web: *compilers*, who usually copied text from Web sources into their own essays and lacked adequate cognitive processing of the collected information; and *authors*, who created an original text and showed more cognitive processing information.

(2) On the other hand, **argumentation** is a critical thinking skill that supports deep engagement with ideas and so with content understanding (Jonassen & Kim, 2009). In this line, Nussbaum and Kardash (2005) identified different degrees of integrating arguments and counterarguments in the students' writing essays following the scale below:

1. *Uninterested*. Essay discusses only one side of the issue or has no final conclusion.
2. *Slightly integrated*. Essay has (a) a minor it-depends argument, (b) a minor reservation, or (c) different conclusions stated at the beginning and end of the essay.
3. *Well integrated*. Essay develops substantial counterarguments and rebuttals or a substantial it-depends argument.
4. *Exceptional*. Essay was balanced, with integrative closing paragraph, and it may weigh evidence on two sides.

Lazonder and Rouet (2008) also have shown that students normally face difficulties in obtaining a final product in effective ways, and Raes et al. (2011) pointed out that students show a lack of critical thinking in their content understandings. The fact of articulating a written response to an information-problem is a complex activity in itself, because writing from multiple documents entails complex cognitive processes (Wiley & Voss, 1999), in which students of all ages find many challenges.

Furthermore, different researchers highlighted the **relationship between the IPS process and product** obtained as a result of that process. For instance, Hoffman et al. (2003) found that factors such as the students' use of adequate search strategies, the adoption of assessment strategies towards online information, and the quality of online resources obtained by students were essential to explain the successful development of science conceptual understandings, which were shown in a final essay. In addition, Klein (2004) pointed out that the students who used concrete strategies (i.e., reviewing certain sources) succeeded in constructing new explanations in writing. Other several studies have also reported on the correlation between the appropriateness of the search terms and the selected results evaluation with the quality of the product (Gerjets et al., 2011; Wiley, Goldman, Graesser, Sanchez, Ash, & Hemmerich, 2009).

The studies reviewed above have analysed the relationship between the process and the product performed by children or university students. The study that we are reporting in this chapter is conducted in Secondary Education. Additionally, those studies reviewed previously focused on one IPS skill isolated from the other ones (e.g., Gerjets et al., 2011; Wiley et al, 2009), or were conducted to evaluate an instructional design (e.g., Hoffman et al., 2003). In our study, we aim to analyse the challenges that secondary students face in IPS tasks, considering the IPS process and product as well as their relations. In this analysis, we will focus on knowing the incidence of the development of specific IPS skills and sub-skills in the quality of problem solving performance (or product). We hope that this detailed analysis will give accurate information about the nature of the challenges that secondary students face when solving IPS tasks and will help us to think about well-embedded scaffolds that could be designed in instructional programs in order to develop the students' information-problem solving skills to overcome these challenges.

1.3. Research objectives

The objectives of this study are the following:

1. To provide detailed analyses of the challenges that secondary students face while solving an information-problem task in their everyday classrooms, regarding their IPS process (constituent skills and sub-skills) and product (answers given and essays written by students).

2. To analyse the correlations between the IPS *process* followed to solve a problem using Web information, and the *product* obtained as a result of the resolution of that problem, as well as the correlations between the skills and sub-skills related to the IPS process.

The accomplishment of these objectives will provide insight to allow us to draw inferences about the educational intervention needed by students to develop efficient IPS while using the Web to learn curricular contents at school.

2. Method

2.1. Participants

Forty students participated in this study. All of them were secondary students from the 7th grade, which corresponds to 13-14 year-olds. The students belonged to three urban schools in the city of Lleida (Spain) and they previously did not receive any specific instruction in the IPS process. This sample of students is part of the larger sample described in the introduction of Chapter 4. Every student of each classroom that participated in the study performed the web-task and their performance was recorded. The selection of the students to be analysed was made in a random way *a posteriori* after the performance of the web-tasks, in order not to influence them.

2.2. Design and procedure

Students were evaluated with an IPS task. The task was solved individually and it lasted about 50 minutes. It was conducted as academic content in the regular classroom at school. During the task, each student had to carry out several processes of solving problems through digital information available online. The students were engaged to answer several questions (sub-tasks) during the IPS task, and to write an argumentative essay that would answer the question of whether it would be possible to install a human colony on Mars, and, if so, what difficulties would have to be overcome, and why[19].

[19] For a wider explanation and illustration of the IPS task, consult Chapter 4 (Section 4).

2.3. Data instrument

The IPS task was logged in by using screen capture software called CamStudio 2.0 (technique “logfiles”) in an attempt to record all the actions performed on the computer screen. The purpose of this recording was to obtain data on the problem-solving process based on an IPS task and to analyse both the process and the product performed by the participants during the IPS task in the real context of the classroom in an unobtrusive way.

2.4. Data analysis procedure

We analysed the process followed and the product elaborated by the participants. Regarding the process, we considered two types of information retrieved from the logfiles: constituent skills and sub-skills derived from the coding scheme presented in Chapter 4 (Section 5.1). Regarding the product, we assessed the answers given to the different questions of the task, and the final essay written by the participants. Table 21 shows a summary of the variables analysed and their measurement, and Figure 20 gives an overview of the inter-relation among the variables –the two way arrows in the figure represent the iterative direction among skills, which are not performed in a linear way (Eisenberg & Berkowitz, 1990).

Table 21. Variables analysed and their measurement

Variables		Measurement
Process	Constituent skills: 1. - Defining the problem 2. - Searching for Information 3. - Scanning and Processing Information 4. - Organizing and Presenting Information	Time spent Number of times performed
	Sub-skills: 5. - Search terms (ST) 6. - Selected results (SR)	Appropriateness score
Product	7. - Answers 8. - Elaboration answers 9. - Final essay	Correctness score Level of elaboration Level of explanation

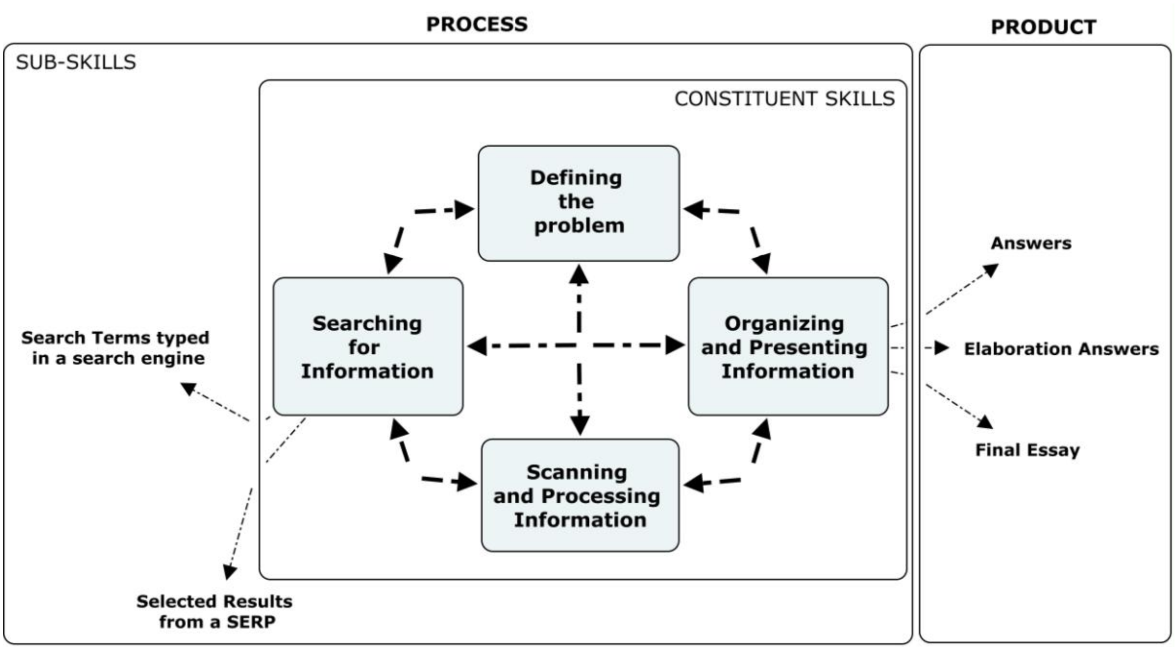


Figure 20. Variables analysed related to process and to product

Finally, we analysed in depth one student as an example of the IPS sequence developed by the participants. Next, we describe in more detail the data analyses procedure of each variable.

2.4.1. Data analyses of the Process variables

The first set of variables analysed referred to the constituent skills: (1) Defining the problem, (2) Searching for information, (3) Scanning and processing information, and (4) Organizing and presenting the information (Brand Gruwel et al., 2005). Each constituent skill was coded, as well as the time spent and the number of times each constituent skill was performed was registered. Short descriptions of these constituent skills are provided in Table 21b.

Table 21b. Coding scheme of constituent skills

Constituent Processes	Short descriptions
Defining the problem	The student is analysing the demand in the IPS task. The computer screen shows the webpage of the assignment demand. The student is not typing anything on it.
Searching for information	The student is navigating on the Web: accessing a search engine, typing search terms on it, or selecting results from a SERP. The computer screen shows a search engine page or a SERP.
Scanning and processing information	The student is navigating on the Web: on a website.
Organizing and presenting information	The student is typing an answer in the IPS task.

The second set of variables analysed referred to the following *sub-skills*: search terms typed (ST) and selected results (SR). Two reasons drove us to only consider those sub-skills: first, several studies have reported on the relationship between the search terms appropriateness and the selected results evaluation with expertise in web-searching (i.e., Lazonder, 2000), and also with the quality of the product (Wiley et al., 2009) and second, the kind of data obtained (logfiles) allows observing specific actions made by the subject with the mouse or keyboard (for example: search terms typed, results selected by clicking on them, etc.).

Search Terms. Each search-term was transcribed verbatim and so each protocol showed each search-term typed during the IPS tasks. Additionally, the appropriateness of each search-term typed scored as ‘appropriate’ (1 point) or ‘inappropriate’ (0 points). This appropriateness considered their context and their demand. For example, the search-term ‘diameter of Mars’ typed in Google when the participant was searching to answer what the diameter of Mars is, was considered ‘appropriate’, whereas ‘conditions of Mars for life’ when the demand was ‘conditions that make a planet suitable for life’ scored ‘inappropriate’ because that search-term refers only to Mars while the demand refers to any planet. In addition, an appropriateness score was calculated as a percentage considering the number of search terms used and the number of appropriate search terms.

Selected Result. Each result that was selected from a SERP by each participant was gathered and so each protocol showed all the selected results during each IPS task. Furthermore, each selected result scored as ‘appropriate’ or ‘inappropriate’. The criteria taken into account to evaluate each search result were both usability and reliability (Gerjets et al., 2011). A selected result was considered ‘usable’ when its content (title, description, URL, and other information available in the SERP) followed the question to be answered, and was considered as ‘reliable’ when the author or source was plausible. Each selected result scored as ‘appropriate’ (1 point) when it was both usable and reliable, and as ‘inappropriate’ (0 points) when it was either not usable or unreliable. Again, an appropriateness score was calculated as a percentage considering the number of total selected results and the number of appropriate ones.

Two raters familiar with the search task, the materials and the coding scheme scored 20% of the protocols. Interrater reliability computed on this subsample of protocols yielded a Cohen’s kappa higher than .80. One rater scored the remaining protocols.

2.4.2. Data analyses of the Product variables

All the answers given and the final essay written by each student were collected and evaluated. The evaluation of the product was carried out in three different ways: answer correctness, level of elaboration of the answers, and level of explanation of the final essay.

Answer grade of correctness. Every student answer scored in a binary fashion as either ‘correct’ (1 point) or ‘incorrect’ (0 points). A correctness score were calculated by considering the percentage between the number of correct answers given and the maximum number of points to be obtained (16 points).

Answer level of elaboration. Seven questions out of 16 required an elaborated answer from the students. Thus, such questions were scored as correct or incorrect, and also coded by one of the following eight graded categories, as are summarized in Table 22.

Table 22. Coding scheme of the answers' level of elaboration

Level of elaboration	Category	Short description: The student…
1	No answer	…did not answer the question
2	Improperly Copy & Paste	…copied and pasted improper information to the question
3	Incorrect or incomplete	…gave an incorrect or incomplete answer to the question
4	Copy & Paste with Irrelevant Information	…copied and pasted a correct answer, but (s)he added irrelevant information that the question did not require
5	Copy & Paste	…copied and pasted a correct answer
6	Elaboration on the content	…answered the question by including one or more of the following elements: translation from another language, insertion of own words, enumeration of concepts
7	Integration of the Information	…answered the question by explaining with own words, comparing, or linking concepts
8	Integration of the Information and Argumentation	…answered the question by using the following elements: own argumentation, own comments, giving examples, and presence of connectors (because, although, it means, in such a way,...)

Final essay's level of explanation. In order to analyse the nature and quality of the knowledge produced by students at the end of the Web-based task, the mean level of explanation was analysed across the students' productions. Each content idea constructed by students to answer the main activity question was classified using a four-step scale starting from two categories related to the description of facts: (1) separate pieces of facts and (2) organised facts, followed by two categories related to explanation: (3) partial explanation and (4) explanation. This scale was based on the scales proposed by Perkins et al. (1995), Hakkarainen (2003), and Nussbaum and Kardash (2005).

Every student answer or essay was reviewed by two experts. In the few cases in which the codes or scores were different between the raters, the final score was derived from a consensus between them.

2.5. Correlations

Pearson correlation coefficient was used to determine the relationship among process and product, and between process variables, with 95% and 99% confidence intervals (SPSS version 18.0 software).

2.6. IPS sequence: an example

In order to gain more insight about the process and product performed by the students while solving an information-problem, we will examine in depth the IPS sequence performed by one student (case study), and we present this analysis by means of a description and a graphical illustration.

3. Results and discussion

In this section, first we present and discuss the results obtained about the process (constituent skills and sub-skills), and the product (answers and essays). Second, we analyse their correlations. Finally, we present the analyses of the case study, in relation with the previous results.

3.1. Process

3.1.1. Constituent skills

As can be seen in Table 23 the entire activity lasted a mean of 40:34 minutes (*SD*=7:15 minutes) and was performed by a mean of 112.2 number of times of constituent skills (*SD*=35.8 times). Comparing the time spent and the number of times (frequency) of each skill, a high amount of number of times each skill was performed can be appreciated, which means that the participants clicked very fast and switched frequently among skills. Previous studies found that secondary students did have more iterations between 'searching' and 'scanning' than adults, and this behaviour was considered as an indicator of a lack of reflection (Brand-Gruwel et al., 2009).

Table 23. Constituent skills: time spent (in minutes) and number of times

	Time spent		Number of times	
Constituent skills	**M**	**SD**	**M**	**SD**
Defining the problem	8:46	2:53	31.8	9.4
Searching for Information	8:30	3:59	22.5	10.6
Scanning-processing Information	14:23	4:20	41.4	16.1
Organizing-presenting Information	8:54	5:18	16.5	9.0
Total	*40:34*	*7:15*	*112.2*	*35.8*

3.1.2. Sub-skills

The two sub-skills measured in this study were 'search terms' typed in a search engine, and 'selected results' from the SERP retrieved by a search engine. The mean of the correctness percentages were 52.94% and 64.71%, respectively.

These results are in line with previous research. The most problematic sub-skills related to the skill 'searching for information' are: 'specify search terms' and 'judge search results' (Walraven et al., 2008). As regards the first sub-skill (*search terms* typed in a search engine), it has been stated that formulating effective searching queries is difficult for most Web users (MaKinster et al, 2002). Regarding the second sub-skill (*selected results* from a SERP), secondary students tend to click too fast on a link without much reflection (Brand-Gruwel et al., 2009), and most of them have difficulties when evaluating Web information in terms of relevance and reliability (Gerjets & Hellenthal-Schorr, 2008). In addition, it has been reported that novices are less efficient at locating useful websites (Lazonder, 2000; MaKinster et al., 2002).

It can be concluded that the participants analysed in this study demonstrated patterns of novice information-problem solvers, characterized by a lack of reflection in shifting between each skill, in typing search terms, and in selecting results.

3.2. Product

The students' answers scored in a binary fashion as either correct (0 points) or incorrect (1 point). The mean obtained by the group was 6.90 (*SD* = 4.29). The maximum score possible was 16 points, which means that only 43.12% of the students' answers were correct.

As regards the *level of elaboration*, Figure 22 shows the means of each category, in a relative fashion. 53.21% of the questions were not answered (which means that students did not find the information searched for) and 16% were incorrectly answered. 25% of the questions were categorized as 'elaboration on the content' and a very little percentage scored as 'integration of the information', which reveals very little transformation of the information (Wiley & Voss, 1999). Contrary to previous studies (i.e., Raes et al, 2011; Wang et al., 2011), the participants of our study used the copy-and-paste strategy in a low proportion. This might be due to the type of IPS task to be solved.

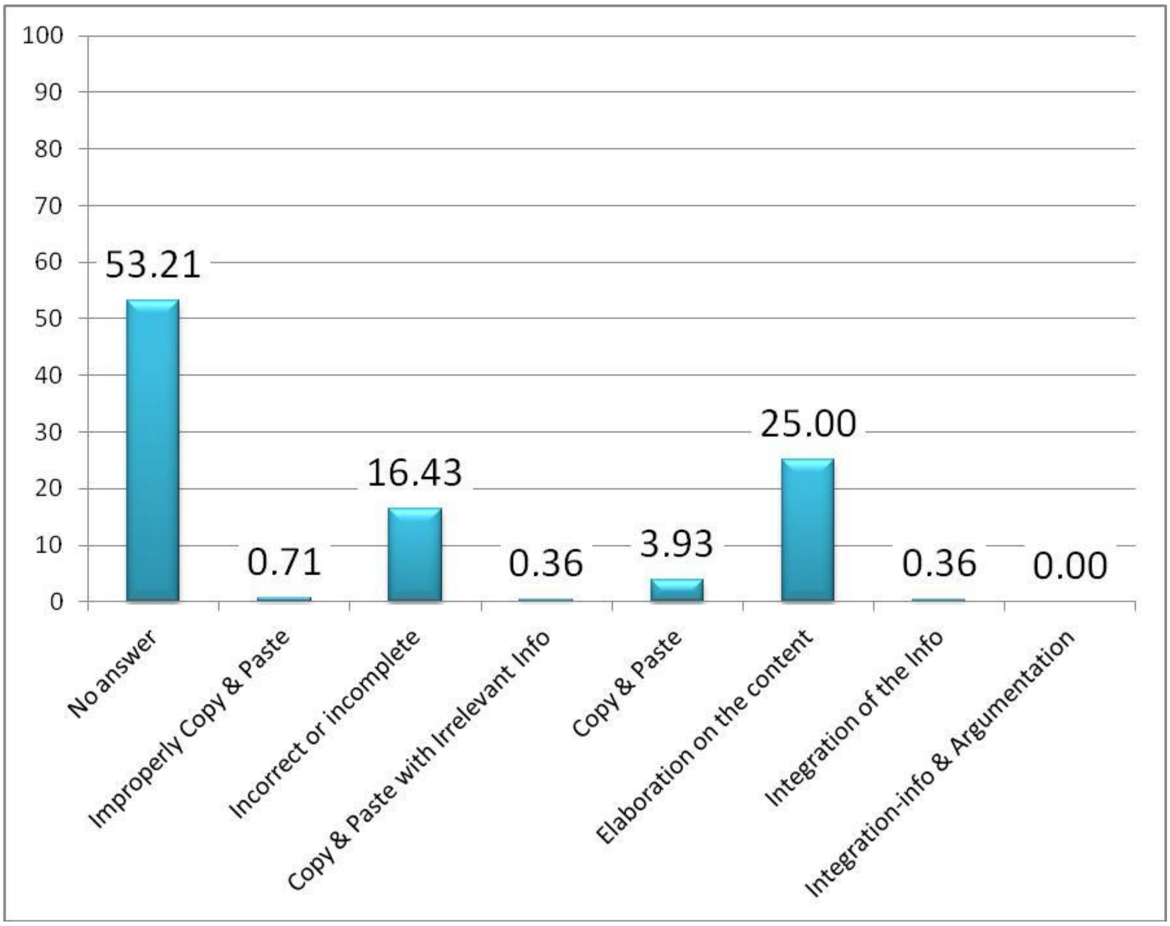


Figure 22. The answers' level of elaboration (in relative fashion)

Concerning the *level of elaboration of the final essay* written at the end of the IPS task, the results obtained by students are shown in Figure 23. Twenty-seven students (67% of participants) did not answer –they did not find useful information on the Internet–; one third of participants wrote their essay based on facts (categories 1 and 2) and none of the students were categorized as explanation fashion (categories 3 and 4), which clearly shows a lack of understanding (Hakkarainen, 2003).

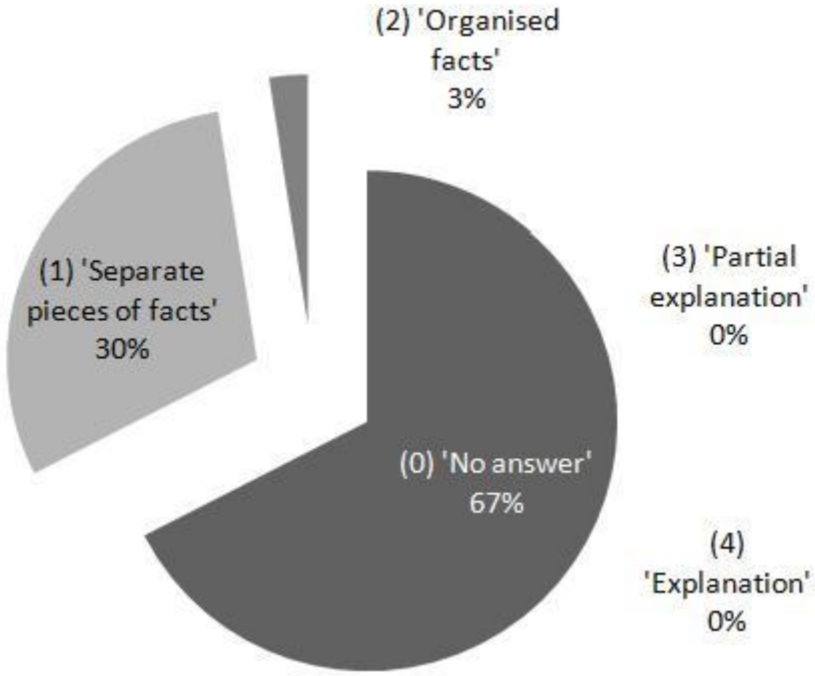


Figure 23. Level of explanation in the final essay

Considering the results of this section, it can be concluded that the participants of this study showed challenges in performing the product, since they reached low scores in the answers' grade of correctness, the answers' level of elaboration, and the essays' level of explanation, as a result of the IPS task.

3.3. Correlations

As can be appreciated in Table 24, there is a high positive statistical correlation between the variables related to process and the variables related to product. Regarding the constituent skills, the higher frequency of skill performed the higher the answers' grade of correctness and level of elaboration or explanation. This happens in all the constituent skills except one –'searching for information'. The selection of a result from a SERP –and consequently appearing a new website– represents a shift from the skill 'searching for information' to the skill 'scanning-processing information'. Contrarily, reflecting about the results to be selected signifies fewer times of shifting, due to the selection of more appropriate results. This means that students should perform this constituent skill fewer times, by reflecting before selecting results from a SERP, as was referred to in previous discussed findings in this section.

On the other hand, a higher level of appropriateness of *search terms* or *selected results* also correlated with the constituent skill ‘searching for information’. However, what is interesting in this point is the importance of saving time in ‘searching for information’, in order to have enough time to perform other necessary skills as ‘organizing-presenting information’. In fact, the higher frequency of ‘searching for information’ did not correlate with the skill ‘organizing-presenting information’ in our study, probably because students who spent a lot of time trying to type more appropriate search terms or to select more appropriate results, did not have plenty of time to organize and present the information, as can be appreciated in the illustrated example (Figure 24) shown in the following sub-section.

Finally, the higher level of appropriateness of the sub-skills *search terms* or *selected results* the higher the answers’ correctness, which show that these sub-skills are critical to find and present correct information (Gerjets et al, 2011; Wiley et al., 2009).

Table 24. Correlation between process (constituent skills and sub-skills) and product (answers and final essay)

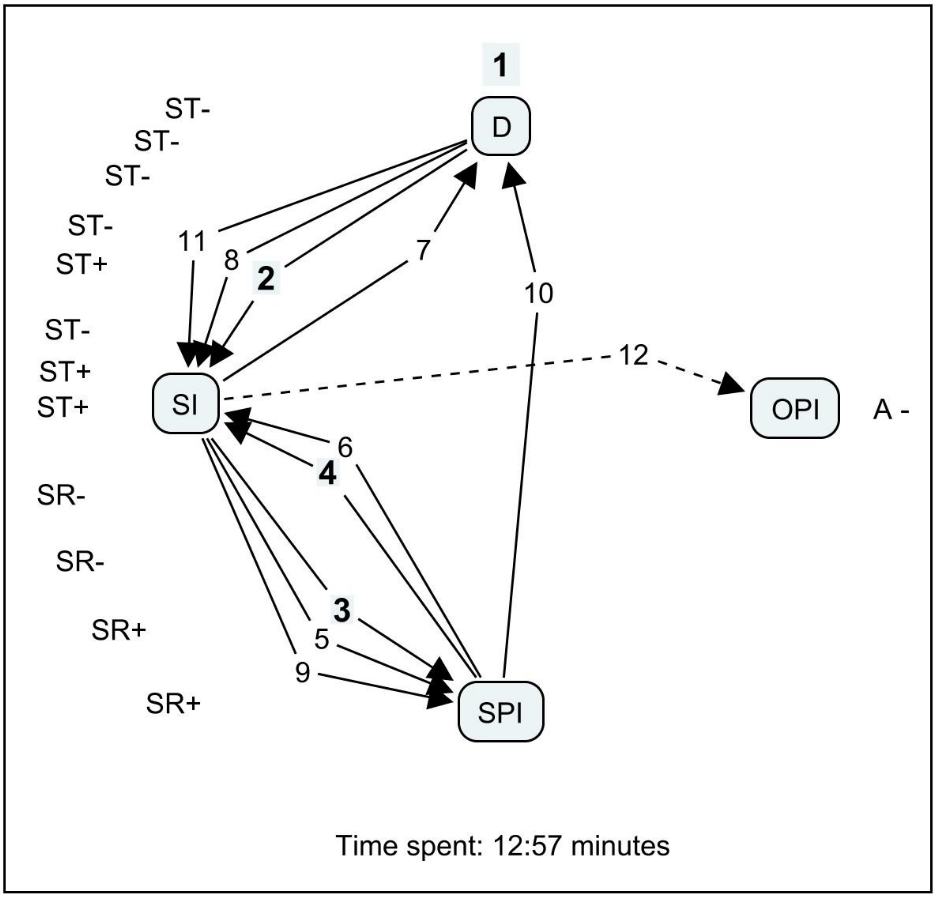
	Variables related to process						Variables related to product		
	Defining problem (number of times)	Searching for info. (number of times)	Scanning-processing info. (number of times)	Organizing-presenting info. (number of times)	Sub-skill Search-terms (appropriate)	Sub-skill Selected results (appropriate)	Answers' correctness	Answers' elaboration level	Final essay's explanation level
Defining problem	1.00	.377**	.706**	.553**	.244	.307*	.570**	.491**	.303*
Searching info		1.00	.473**	.103	.776**	.627**	.311*	.209	-.172
Scanning-processing			1.00	.602**	.251	.581**	.695**	.580**	.101*
Organizing-presenting				1.00	.143	.278	.734**	.654**	.464**
Sub-skill Search- terms					1.00	.545**	.324**	.187	.065
Sub-skill Selected results						1.00	.353*	.286	-.192
Answers' correctness							1.00	.800**	.307*
Answers' elaboration level								1.00	.329*
Final essay's explanation level									1.00

* p < .05; ** p < .01 (two-tailed)

3.4. IPS sequence: an illustrated example

The main goal of this study was to analyse the challenges that secondary students face while solving a problem through digital information to learn curricular contents at school. In order to gain better understanding of the IPS process and product performed by participants, an example is illustrated and described in this section. Figure 24 shows the sequence in which a representative participant, Axel[20], executed skills and sub-skills, as well as the answer given to one of the questions of the IPS task –'what are the conditions that a planet must have for life to be held in it'. The numbers in the illustration indicate the order in which every skill was performed. The reader is suggested to follow the numbered arrows in the illustration together with the descriptions below, to better understand the sequence. The first numbers in the illustration have been highlighted for easier access.

[20] This name is not real in order to save the student identity. Axel's case is more widely described in Study 4 (Chapter 8) in this dissertation.



LEGEND:

CONSTITUENT SKILLS

D: Defining the problem
SI: Searching for Information
SPI: Scanning and Processing Info
OPI: Organizing and Presenting Info

SUB-SKILLS

ST: Search Terms typed
SR: Selected Results from a SERP

+ : appropriate
- : inappropriate

ANSWERS

A: Answer

+ : correct
- : incorrect

Figure 24. IPS sequence performed by Axel to answer one of the questions of the IPS task

(1) *Defining the problem (D)*. The first skill that Axel performed was 'defining the problem', by scrolling down the web-task and positioning the mouse pointer on the paragraph with the instructions to solve the problem.

(2) *Searching for Information (SI)*. Next, he started a new skill by clicking the available link 'Google' and typing a set of search terms in the search engine. Those search

terms were inappropriate (ST-) on account of the demand. A SERP was retrieved, and Axel selected the second hit, which was also inappropriate (SR-).

(3) *Scanning and Processing Information (SPI)*. Then, the new webpage appeared and Axel scrolled down through the page. There was not useful information to solve the task, and Axel clicked on the 'back' button.

(4) *SI*. The SERP opened up again. Axel typed in the search terms inappropriately (ST-) and selected an inappropriate result (SR-).

(5) *SPI*. A new webpage opened up, whose information was irrelevant to solve the task. Axel clicked on the 'back' button.

(6) *SI*. Again, the search engine opened up and a new set of search terms were inappropriately typed (ST-).

(7) *D*. Axel positioned the mouse for a few seconds on the screen that displayed the problem.

(8) *SI*. He came back to the search engine (ST-/ST+). When the SERP appeared, he selected an appropriate result (SR+).

(9) *SPI*. The webpage was available and Axel selected an appropriate link (SR+) and a new page was retrieved.

(10) *D*. Then, Axel accessed the page where the problem was explained.

(11) *SI*. After that, the student accessed the search engine (ST-/ST+). When the new SERP was retrieved, the student selected a result (SR+) and afterwards he returned to the SERP. Then, he typed another search-term (ST+).

(12) *Organizing and presenting information (OPI)*. Finally, the student organized-presented the information by accessing the page of the problem and typing in an answer to the question, which was incorrect-incomplete (A-), and had not been found in any of the webpages visited during his web-search.

To sum up this sequence, Axel performed 12 constituent skills and spent 12:57 minutes on them. After several attempts, he came up with appropriate search terms and appropriate selected results. However, he was not able to find information to solve the problem successfully.

It is important to highlight that **a unique mistake** in one point of solving the information-problem might result in a lack of success in the result, or, at least, it might provoke a waste of valuable time to solve the whole problem, as was discussed in previous sub-sections of this chapter. Some previous studies already reported that novices are more unsuccessful than experts in finding an appropriate website and the information needed (i.e., Lazonder, 2000); therefore, they face more difficulties to obtain a product of quality. According to Hoffman et al. (2003), students might develop accurate and in-depth understandings if they use search and assess strategies appropriately, and if resources are thoughtfully chosen.

Another interesting point derived from both the correlations and the illustrated example is the close relationship among the constituent skills. For example, after several attempts to specify search terms in the search engine, Axel consulted the demand (‘defining the problem’, number 7 in the sequence). Then, he got a correct search-term (‘searching for information’, number 8 in the sequence). This relationship among the skills leads us to highlight **the need of each constituent skill** in order to facilitate the success of the IPS task.

4. Conclusions and educational implications

The main goal of this second research study is to give insight about the challenges that secondary students face while solving a problem with digital information, in order to draw educational implications about the features of the intervention needed by students while using the Web to learn curricular contents at school.

Our results revealed that secondary students face several challenges in the development of an efficient IPS process (constituent skills and sub-skills) and in order to give a product as a result of the resolution of the problem. In addition, variables related to process highly correlate with variables related to product, which advise that the enhancement of the skills and sub-skills lead to an improvement of the solution of the IPS task. Furthermore, variables of the process are also related with each other, which may mean that each constituent skill and sub-skill is necessary to be considered in order to warrant more successful problem-solving behaviours.

Therefore, it is necessary to help secondary students to enhance all their IPS skills and sub-skills, as well as their abilities in applying the final product. To do that, teachers at school should be aware of the challenges that students usually face in IPS tasks at their classrooms, in order to support students to overcome such difficulties.

Taking into account the considerations discussed above as well as the theoretical and methodological contributions analysed in Chapters 2 and 3, we propose the design of an instructional process based on the following three key instructional principles: (1) **embedding** the IPS skills in curricular activities, (2) **structuring** the students' problem-solving, and (3) **supporting** the student's problem resolution with specific scaffolds, as we expound in the following paragraphs.

(1) The first key principle that we suggest is '**embedding**' instruction in a meaningful and real context –classroom– spanning a long period of time, and for learning different curricular contents using Web information and across the curriculum (different subjects). This kind of instruction might facilitate the development and transfer of the IPS process and product to other contexts (Brand-Gruwel et al., 2009).

(2) Relating the second key principle, '**structuring'** instruction, it is worth highlighting the importance of guiding students through the whole process of the resolution of the information-problem, and therefore scaffold to accomplish all the steps needed to successfully solve that problem, by means of providing a layer of structure between the student and the Internet (Segers & Verhoeven, 2009).

(3) Finally, as regards to the principle of '**supporting'** instruction, we claim the necessity to design an instruction which could provide scaffolds in each IPS skill and sub-skill needed to tackle information-problems and in constructing the final product. Scaffolds are temporary supporting structures to promote student learning of complex problem-solving or reasoning (Bransford, Brown, & Cocking, 2000). Furthermore, scaffolding to support IPS skills is highlighted as an important instructional method in computer-based learning environments (Bannert & Reimann, 2011). Thus, the scaffolds could be embedded in the whole learning task, adapted to the different kinds of students and tasks, and should gradually lose intensity as the instructional process progresses.

Instructional process might be scaffolded during the whole learning task by means of questions, worksheets, scripts, or prompts (Stadtler & Brome, 2008). These scaffolds could be displayed on screen at certain times during the IPS process, and also while performing the product, as suggested by Bannert and Reimann (2011). For instance, at the beginning of the task, students may be engaged in an in-depth analysis of the problem to be solved. By means of workspaces, students are asked to activate their prior knowledge; and a set of questions may guide students to plan a strategy to solve the problem. A similar procedure can be planned for the other skills or sub-skills needed to tackle information-problems: searching for information, scanning and processing information, and organizing and presenting information.

To conclude, the second research study of this dissertation reported in this chapter, examined in depth the challenges that secondary students face when solving a problem using digital information to learn curricular contents. Our findings draw inferences to help secondary students to enhance their IPS skills in their everyday classrooms, in order that they could improve their digital competences that may allow them an adequate use of Web information.

* * *

In the following (Chapter 7), we present the third research study of this dissertation, whose main objective is to assess the effect of an embedded, structured, and supported IPS instruction in secondary classrooms, as well to analyse the differences between the groups of students who received and did not receive that instruction in terms of skills and sub-skills. Furthermore, the fourth and last study (Chapter 8) will study in a more qualitative and in-depth way such differences between students.

Chapter 7. Improving Information-problem solving in Secondary Education through embedded instruction (Study 3)

This chapter presents the third study[21] of this dissertation. It consists in an investigation of the effects, on the development of Information-problem solving (IPS) skills, of a long-term embedded, structured and supported instruction in Secondary Education. Forty secondary students of 7th and 8th grades (13-15 years old) participated in the 2-year IPS instruction. Twenty of them participated in the IPS instruction, and the remaining twenty were the control group. All the students were pre- and post-tested in their regular classrooms, and their IPS process and performance were logged by means of screen capture software, to warrant their ecological validity. The IPS constituent skills, the web-search sub-skills and the answers given by each participant (task performance) were analysed. The main findings of our study suggested that experimental students showed a more expert pattern than the control students regarding the constituent skill 'defining the problem' and the following two web-search sub-skills: 'search terms' typed in a search engine, and 'selected results' from a SERP. In addition, scores of task performance were statistically better in experimental students than in control group students. The paper contributes to the discussion of how well-designed

[21] An earlier version of this chapter has been published as: Argelagós, E. & Pifarré, M. (2011). Improving Information Problem Solving skills in Secondary Education through embedded instruction. *Computers in Human Behavior*, *28*(2), 515-526. doi:10.1016/j.chb.2011.10.024.

and well-embedded scaffolds could be designed in instructional programs in order to guarantee the development and efficiency of the students' IPS skills by using net information better and participating fully in the global knowledge society.

1. Introduction

Nowadays, the World Wide Web (WWW) has become one of the most important information sources in both personal and academic life. Students in Secondary Education use the Internet widely for both leisure and school assignments; however, it is a widely accepted fact that the complex cognitive processes involved in gathering and processing information from the Web are not instinctively acquired (Puustinen et al., 2009; Wood, 2009). Secondary students have serious difficulties in such skills as identifying the information needed, searching, locating, and processing information from the Web (Wallace et al., 2000). To overcome this problem, educational institutions have the duty to instruct their students explicitly and extensively, since those skills are amenable to improvement through instruction (Wiley et al, 2009). The main goal of this study is to analyse the effect of a long-term embedded, structured, and supported instruction on the development of students' information-problem skills. To accomplish this goal, in the next sections, we will first remind the concept of information-problem solving (IPS) process and the students' difficulties in developing it. Next, we will analyse how our study plans tackle and overcome the limitations of previous instructional studies by helping students to develop efficient IPS skills. Finally, we will formulate the research questions that guide our study.

1.1. Information-problem solving

Gathering and processing information from the Web involves complex cognitive processes and requires from individuals to identify information needs, locate information sources, extract and organize information from each source, and synthesize information from a variety of sources. This set of interrelated abilities is referred to as information seeking (Marchionini, 1995; Wallace et al., 2000; Wilson, 1999), Information Literacy (American Library Association, 1998; Shapiro & Hughes, 1996;

UNESCO, 2006) or Information-problem solving (Eisenberg & Berkowitz, 1990; Land & Green, 2000; Moore, 1995; Wolf, Brush, & Saye, 2003).

Different models have described the IPS process as it can be segmented into several sub-processes (Brand-Gruwell et al., 2005; Gerjets & Hellenthal-Schorr, 2008). As summarized by Gerjets et al. (2011), a collection from several existing models yields five important processes: (1) an information problem is defined, (2) normally, a search engine is selected, where a query with search terms is entered and sent off. Subsequently, a 'search engine result page' (SERP) with a list of search result links is retrieved to the user, (3) available search results are scanned, evaluated and selected for further inspection, (4) after accessing a selected webpage, the information is scanned, evaluated with regard to its relevance for the search goal, and in case of relevance, information is extracted for further processing, (5) the information from different webpages is integrated towards a solution of the information-problem[22].

Researchers agree that all these processes are not instinctively acquired by students, instead they are processes which need to be developed (Puustinen et al., 2009; Wood, 2009). This has become progressively more important with the increase of technology-enhanced learning and Information and Communications Technology based resources which require more sophisticated search processes (Walraven et al., 2008); however, secondary students possess limited online information and critical evaluation skills (Ladbrook & Probert., 2011), and face many problems when exposed to an IPS task.

Different studies have already reported that teenagers struggle in the development of the IPS processes. These studies show that teenagers have difficulties in developing the different cognitive processes involved in solving an information-problem, as described in Chapter 2 (section 3) and in the second study of this dissertation (Chapter 6). Considering all these difficulties, it is increasingly recognized that explicit IPS instruction is needed to achieve an adequate level of IPS expertise (Johnston & Webber, 2003; Larkin & Pines, 2005; Walton & Archer, 2004; Brand-Gruwel & Gerjets, 2008). Researchers also highlight that IPS instruction should be well-designed and well-integrated in the curriculum. This is precisely the focus of this

[22] More information about the IPS process can be consulted in Chapter 2 (section 2.3) in this dissertation.

research, namely the effect of well-designed and embedded instruction across secondary curriculum.

1.2. Instructional support in Secondary Education

One of the main instructional principles used in our study is that IPS skills might be acquired embedded within a relevant and meaningful context and not through isolated assignments (cf. Kuiper et al., 2008). As explained in Chapter 3, many effective embedded instruction research studies have been conducted in Primary Education; however, embedded instruction studies in Secondary Education are scarce and most IPS instruction in Secondary Education is implemented as separate courses, loosely connected to the curricular contents.

In view of the conclusions from previous studies on IPS instruction and on the challenges that students have to face, this study aims to prove that an efficient design, implementation and analysis of IPS instruction in Secondary Education should take into account embedded, structured, and supported variables. Our study integrates these three variables in the design of the instruction implemented and evaluated in our research work. It can briefly be described as: (1) *embedded* in a meaningful and real context (classroom) spanning two academic years with a view to developing IPS skills and task performance, and learning from the Web, (2) *structured* by designing Web-based tasks which follow the WebQuest structure (Dodge, 1995), and (3) *supported* by providing scaffolds in the several skills needed to tackle information problems[23].

1.3. Research questions

The purpose of our research is to study the effect of an embedded, structured, and supported IPS instruction on IPS skills and task performance. We hypothesize that students who participated in the integrated instruction on IPS will execute the IPS skills

[23] For a wider explanation of the IPS instructional process, consult chapter 3 (section 3) of this dissertation.

and its constituent skills more adequately and intensively. The research questions of our study are the following three:

1. What are the differences between students who participated in the embedded IPS instruction and students who did not participate, regarding the development of IPS skills and sub-skills during the resolution of an IPS task? Do the instructed students show a more expert web-searching pattern than the non-instructed students?

2. Do the instructed students obtain a better task performance (in terms of results) than that of non-instructed students?

3. Is there a correlation between the process (constituent skills and sub-skills) and the task performance in the IPS tasks executed by the participants?

2. Method

2.1. Participants

Forty students participated in this study. All of them were students in year 7th and 8th (13-15 years old), Secondary Education. The students belonged to three urban schools in the city of Lleida (Spain), as explained in Chapter 4 and in the second study of this dissertation (Chapter 6).

2.2. Design and procedure

The nature of this study was quasi-experimental and was set up according to a pre-test post-test control-group design. In order to maintain the natural setting of the classroom, one school was established as the control group, while the other two acted as the experimental group. From the 40 participants, 20 of them constituted the control group, and the remaining 20 were randomly selected from both experimental schools and constituted the experimental group.

In order to minimize possible variables which could affect the reliability of participants' selection in the experimental-control group, the following variables were taken into consideration and hence monitored: socio-demographic, psycho-pedagogical, and task performance variables. As regards the *socio-demographic* variable, the three schools are comparable since they have similar features: school type (public), socio-economic status of school students (middle class), and school location (urban). Regarding the *psycho-pedagogical* variable related to the study reported in this paper, the schools did not participate in any teaching innovation project involving the use of ICT. Furthermore, all the students were assessed by means of a pre-test focusing on their initial level of performance in the resolution of an IPS task -*task performance* dependent variable (see section 2.4. of this chapter for an extensive description of dependent variables). A *t*-test revealed no statistically significant differences between the two experimental schools (school 1: $N = 9$, $M = 43.79$, $SD = 30.29$; school 2: $N = 11$, $M = 24.06$, $SD = 25.99$; $t(18) = -1.559$, $p = .139$). So from now on, in our study we will consider the two experimental schools as an experimental group.

The quasi-experimental design process had three phases: (1) a pre-test was conducted on control and experimental students at the beginning of the research project; (2) after the pre-test, the students in the experimental group followed the embedded IPS instruction in the secondary curriculum for two academic years, and (3) after these two years the post-test was conducted on all students.

2.3. Materials

2.3.1. Intervention: characteristics of the IPS instructional process

Over two academic years, the students in the experimental group learned the contents of the curriculum areas by means of the teaching methodology routinely used by their teachers, and they were also engaged in an IPS Web-based learning environment embedded in the curricular contents. The control group did not receive that specific IPS instructional process. The IPS Web-based tasks of the instructional process were designed by teachers and researchers, and were devoted not only to training IPS skills, but also to learning curricular contents[24].

2.3.2. Pre- and post-tests

At the beginning of the first academic year and at the end of the second year, both control and experimental groups performed an IPS task as a test. Students solved the same IPS task during the pre- and post-test evaluation. They solved it individually

[24] A wider description of the instructional process can be found in the chapter 3 (section 3) in this dissertation.

and each IPS task took about 50 min. It was performed in the real context of the classroom in order to ensure *ecological validity* (Wopereis & van Merriënboer, 2011).

The IPS task was divided into two main parts. In part 1, participants were engaged in completing a concept map to collect information about planet Mars (physical characteristics, orography, atmosphere, climate, satellites). In part 2, participants had to accomplish three steps: (2.1) explaining, using information from the WWW, the conditions a planet must fulfil to make life possible on it, (2.2) describing the favourable and unfavourable conditions of Mars, and (2.3) writing a final essay that would answer the question of whether it would be possible to install a human colony on Mars, and, if so, what difficulties would have to be overcome, and why.

2.4. Data analysis procedure

Pre- and post- IPS tasks of each participant (N = 40) were logged in by a screen capture software called CamStudio 2.0 ("logfiles" technique) in an attempt to record all the actions performed on the computer screen. The purpose of this recording was to obtain data on the problem-solving process based on an IPS task and to analyse both the process and the product performed by the participants during the IPS task in the real context of the classroom in an unobtrusive way. One logfile per student was obtained. A total amount of 80 logfiles were obtained (that is, two tests by two conditions by 20 students).

Each logfile was observed in detail and transcribed. Thus, a protocol was obtained from each logfile. Each protocol consisted of three main parts. The first part was devoted to the constituent skills and contained the following columns: time line, constituent skill performed and duration of the skill performed. The second part was devoted to the web-search sub-skills and consisted in the following columns: search terms typed, appropriateness of the search terms, selected results, and appropriateness of the selected results. The third part of each protocol was about the product (task performance) and contained the following columns: students' answers, and correctness of the answers.

Two raters, familiar with both the IPS task and the materials (in particular, with the coding scheme explained in chapter 4, section 5.1, in which is based the scoring system presented in this study), coded 15% of all the protocols. Interrater reliability computed on this subsample of protocols yielded a Cohen's Kappa higher than .80. One rater scored the remaining protocols.

As a result of the data analysis of the pre- and post-tests, different dependent variables were obtained for the IPS process (*constituent skills* and *sub-skills*) and for the IPS product (*task performance*). Table 25 shows every variable together with their measurement. In the next sub-sections, the dependent variables analysed in this study are described.

Table 25. Dependent variables and their measurement

Dependent variables		Measurement
Process	Constituent skills: 1. - Defining the problem 2. - Searching for information 3. - Scanning and Processing Info 4. - Organizing and Presenting Info	Number of times performed
	Web-search sub-skills: 5. - Search terms 6. - Selected results	Appropriateness of the search terms and the selected results
Product	7. - Task performance	Answers' correctness score

2.4.1. Dependent variables related to constituent skills

The first part of each protocol obtained refers to the constituent skills: (1) defining the problem, (2) searching for information, (3) scanning and processing information, and (4) organizing and presenting the information (Brand Gruwel et al., 2005). Each constituent skill was coded, therefore the *number of times* spent on each constituent skill was recorded. Short descriptions of these constituent skills can be seen in Table 26.

Table 26. Coding scheme of constituent skills

Constituent skills	Short descriptions
Defining the problem	The student is analysing the demand in the IPS task. The computer screen shows the webpage of the assignment demand. The student is not typing anything on it.
Searching for information	The student is navigating on the Web: accessing a search engine, typing search terms on it, or selecting results from a SERP. The computer screen shows a search engine page or a SERP.
Scanning and processing information	The student is navigating on the Web: on a website.
Organizing and presenting information	The student is typing an answer in the IPS task.

2.4.2. Dependent variables related to Web-search sub-skills

The second part of each protocol retrieved refers to the following sub-skills: *search terms typed* and *selected results*. Two reasons drove us to only consider those sub-skills: first, several studies have reported on the relationship between the search terms appropriateness and the selected results evaluation with expertise in web-searching (Lazonder, 2000; Monereo et al., 2000), and also with the quality of the task performance, i.e., the product (Gerjets et al., 2011; Ladbrook & Probert, 2011; Tu et al., 2008; Wiley et al., 2009) and second, the kind of data obtained (that is, a logfile of the actions performed by each student) allows observing specific actions made by the subject with the mouse or keyboard (for example: search terms typed, results selected by clicking on them, number of times they visit a website, etc.).

Search terms. Each search-term was transcribed verbatim and so each protocol showed each search term typed during the IPS tasks. Additionally, the appropriateness of each search-term typed scored as 'appropriate' (1 point) or 'inappropriate' (0 points). This appropriateness did not take into account only the number of keywords typed (Tu et al., 2008), but also considered their context and their demand, as suggested by Kuiper et al. (2008). For example, the search-term 'diameter of Mars' typed in Google when the participant was searching to answer the demand *Mars' diameter*, was considered as 'appropriate', whereas 'conditions of Mars to life' when the demand was *conditions that make a planet suitable for life* scored as 'inappropriate' because that search-term refers only to Mars while the demand refers to any planet. In addition, an appropriateness score was calculated as a percentage considering the number of search terms used and the number of appropriate search terms.

Selected results. Each result that was selected from a SERP by each participant was gathered and so each protocol showed all the selected results during each IPS task. Furthermore, each selected result scored as 'appropriate' or 'inappropriate'. The criteria taken into account to evaluate each search result were both *usability* and *reliability* (Gerjets et al., 2011; Rouet et al., 2011; Walraven et al. 2008; Wiley et al., 2009). A selected result was considered 'usable' when its content (title, description, URL, and other information available in the SERP) followed the question to be answered, and was considered as 'reliable' when the author or source was plausible. Each selected result scored as 'appropriate' (1 point) when it was both usable and reliable, and as 'inappropriate' (0 points) when it was either not usable or unreliable. Again, an appropriateness score was calculated as a percentage considering the number of total selected results and the number of correct ones.

2.4.3. Dependent variable 'Task performance'

Students' answers also scored in a binary fashion as either 'correct' (1 point) or 'incorrect' (0 points). The maximum score possible was 16 points, and such a correctness score were calculated by considering the percentage between the number of correct answers given and the maximum number of points to be obtained.

2.4.4. Statistical analyses

SPSS version 18.0 software was used for the analysis of the data obtained and repeated measures ANOVA were calculated for each dependent variable, with confident intervals between 95% and 99%, in order to compare the effect of the IPS embedded instruction on each dependent variable in experimental and control conditions. In addition, the Pearson correlation coefficient was used to determine the relationship between constituent skills, sub-skills, and task performance, with 95% and 99% confidence intervals.

3. Results

In this section, we will first show the results obtained in the analyses of the pre-test for the experimental and control groups, in order to identify possible differences. Then, we will show the results obtained by repeated measures ANOVA to compare pre-post experimental condition in order to answer the first and second research questions of our study. Finally, we will show the correlation analyses between the variables to give an answer to the third research question of our study.

3.1. Analyses of the pre-test

As seen in table 27, there are no significant differences between experimental and control groups in the pre-test as regards the dependent variables related to the *sub-skills*, both ‘search terms’ and ‘selected results’, as well as the dependent variable related to *constituent skills* ‘organizing-presenting information’.

Closer analysis reveals that the *constituent skills* performed by the experimental and control students in the pre-test, *t*-test showed significant differences in the following skills: ‘defining the problem’, ‘searching for information’, ‘scanning-processing information’. In addition, the dependent variable ‘task performance’ also revealed differences. It is worth noting that descriptive statistics showed that experimental students obtained lower means in these variables compared with those obtained by the control group students.

Table 27. Dependent variables related to constituent skills, sub-skills, and task performance in the pre-test. Means (in brackets, SD), t and p values.

Dependent variables	Experimental group		Control group		*t*	*p*
Constituent skills						
1.- Defining the problem	27.2	(9.6)	36.4	(6.9)	3.494	.001
2.- Searching for info	18.1	(8.3)	26.9	(10.9)	2.890	.006
3.- Scanning-processing info	34.7	(17.6)	48.2	(11.3)	2.894	.006
4.- Organizing-presenting info	15.8	(11.3)	17.3	(6.0)	.542	.592
Sub-skills						
5.- Search Terms (score)	52.9	(23.2)	54.5	(20.4)	.229	.820
6.- Selected Results (score)	61.4	(23.1)	71.3	(18.1)	1.504	.841
7.- **Task performance**	32.9	(28.7)	49.7	(20.1)	2.140	.039

Constituent skill ‘organizing-presenting information’ and sub-skills were performed by both groups of students without significant differences. Differences found in some constituent skills’ frequencies and in task performance will be taken into account during the interpretation of the results in the following sections, in order to guarantee the validity of the results on the impact of the IPS instructional process.

3.2. Constituent skills: pre-post analyses

As shown in Table 28, during the post-test, experimental group invested a higher number of times on the constituent skills ‘defining the problem’ and ‘organizing and presenting information’ during the IPS task resolution. By contrast, the control group invested more number of times on the skills ‘searching for information’ and ‘scanning and processing information’ in comparison with the experimental group. Despite of the fact that the control group already showed a significant higher frequency in the pre-test, the results revealed a different proportion between the number of times performed on the skills ‘search for information’ and ‘scanning and processing’ by experimental and control groups during the post-test. Although both groups invested a higher number of times during their post-test on ‘scanning and processing’ than on ‘searching’, the proportion of the experimental group was more than doubled that of the control group. Although repeated measures ANOVA did not show significant differences on those means in terms of interaction with the independent variable, they revealed an encouraging trend, namely that the experimental students did not need to perform so many times the constituent skill ‘searching for information’ due to more efficiency (as demonstrated in the following sub-sections) during the searching sub-skills, such as ‘search terms’ typed in a search engine and ‘selected results’ from a SERP.

Table 28. Dependent variables related to constituent skills. Number of times performed during the IPS task. Means (in brackets, SD), F and p values

Dependent variables related to constituent skills	Experimental group				Control group				F values		
	Pre-test		Post-test		Pre-test		Post-test		Between-subjects	Within-subjects	Interaction
Defining the problem	27.2	(9.6)	44.1	(10.2)	36.4	(6.9)	38.4	(8.1)	.581	36.199**	22.498**
Searching for Info	18.1	(8.3)	28.0	(9.2)	26.9	(10.9)	34.7	(14.4)	8.540**	16.090**	226
Scanning-Processing Info	34.7	(17.6)	61.8	(17.3)	48.2	(11.3)	63.0	(19.6)	3.234	39.206**	3.414
Organizing-Presenting Info	15.8	(11.3)	28.4	(11.0)	17.3	(6.0)	25.0	(7.9)	.191	24.555**	1.453

* $p < .05$; ** $p < .01$.

As a conclusion of this sub-section, during the post-test, students from the experimental group invested significantly more times on the skills ‘defining the problem’ and also followed the general trend of performing more times ‘organizing and presenting information’ in comparison with the control group. In addition, experimental students performed more times the ‘scanning and processing’ skills than the ‘searching’ skill. We can conclude that experimental group students used a more expert IPS pattern than control group students (Brand-Gruwel et al., 2005; Lazonder, 2000).

3.3. Sub-skills: pre-post analyses

This section analyses the variables related to sub-skills ‘search terms’ typed in a search engine and ‘selected results’ from the SERP retrieved by a search engine. These sub-skills belong to the constituent skill ‘searching for information’. A repeated measures ANOVA showed that the experimental group reached higher appropriateness’ scores in search terms typed and in selected results from the SERP, as can be seen in Table 29 and in Figure 25.

Table 29. Dependent variables related to sub-skills: Search Terms (ST) and Selected Results (SR). *Means* (in brackets, *SD*), *F* and *p* values

Dependent variables related to sub-skills	Experimental group		Control group		F values		
	Pre-	Post-	Pre-	Post-	Between subjects	Within-subjects	Interaction
ST (score)	52.89 (23.24)	87.12 (13.09)	54.48 (20.44)	56.27 (17.73)	9.255**	25.004**	20.268**
SR (score)	61.40 (23.09)	87.17 (11.26)	71.27 (18.12)	72.38 (9.89)	.446	13.304**	11.190**

* $p < .05$; ** $p < .01$

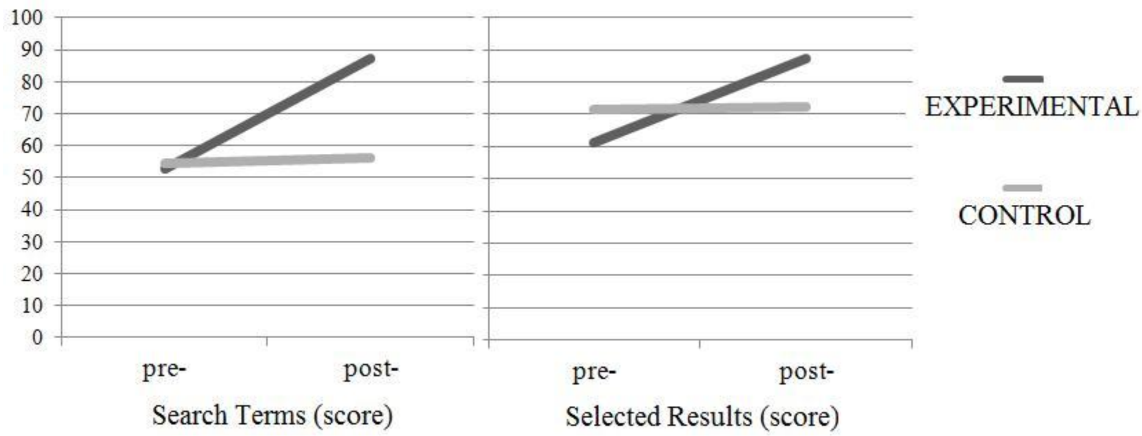


Figure 25. Interaction between pre-post test and experimental-control condition regarding instructional process and the variables related to sub-skills ‘Search terms’ and ‘Selected results’

3.4. Task performance: pre-post analyses

The ANOVA results showed that participants of the experimental group performed their IPS tasks with a significantly higher level of correctness than participants of the control group, as can be seen in Table 30. We can conclude that after the intervention the experimental group was significantly more successful in the variable ‘task performance’ compared with the control group.

Table 30. Dependent variable ‘Task performance’. Means (in brackets, SD), F and p values

	Experimental group		Control group		F values		
	Pre-	Post-	Pre-	Post-	Between-subjects	Within-subjects	Interaction
Task performance	32.94 (28.72)	73.00 (21.02)	49.01 (20.06)	52.33 (16.37)	.108	34.994**	26.908**

* $p < .05$; ** $p < .01$

3.5. Correlation between process and product

Regarding the relation between the process and the product in all the students and in all the tests performed (the 20 experimental students and the 20 control students in their pre- and post-test, as a whole group, $N = 80$), Person’s correlations were calculated among the dependent variables related to constituents skills, web-search sub-skills, and task performance. Table 31 shows the relations among these variables.

As regards the constituent skills, a high correlation was found between the skills ‘defining the problem’ and ‘scanning-processing information’ and also ‘organizing-presenting information’ in terms of number of times performed. In addition, the skill ‘searching for information’ correlated with the skill ‘scanning-processing information’. Finally, the same correlation was found between ‘scanning-processing’ and ‘organizing-presenting’. These findings verify the results shown above. More frequency in ‘defining the problem’ more frequency in ‘scanning-processing’ and ‘organizing-presenting’, but not more frequency in ‘searching’. More attempts in ‘searching’ would reveal poor search ability.

In addition, there was a strong relationship between the web-search sub-skills: ‘search terms’ and ‘selected results’. Furthermore, some of the constituent skills correlated with some web-search sub-skills, as the following. There was a relationship between the number of times performed on ‘defining the problem’ and the appropriateness of the ‘selected results’. Additionally, the number of times performed on ‘organizing-presenting the information’ correlated with the appropriateness of ‘search terms’ and ‘selected results’.

Finally, the high level of task performance of the participants correlated with a high number of times performing the skill ‘defining the problem’ and ‘organizing-presenting information’. A high level of task performance of correctness also correlated positively with the appropriateness scores of ‘search terms’ and the appropriateness of ‘selected results’.

Table 31. Correlation between process (dependent variables related to 'constituent skills' and 'sub-skills') and product (dependent variable 'task performance')

		Constituent skills				Sub-skills		
		Defining problem (number of times)	Searching for info. (number of times)	Scanning-processing info. (number of times)	Organizing-presenting info. (number of times)	Search terms (score)	Selected results (score)	Task performance
Constituent skills	Defining problem (number of times)	1.00	.15	.49**	.42**	.24	.35*	.38*
	Searching for info. (number of times)		1.00	.55**	.92	-.14	-.06	.06
	Scanning-processing info. (number of times)			1.00	.66**	.10	-.28	.23
	Organizing-presenting info. (number of times)				1.00	.36*	.51*	.33*
Sub-skills	Search terms (score)					1.00	.63**	.70**
	Selected results (score)						1.00	.58**
	Task performance							1.00

* $p < .05$; ** $p < .01$ (two-tailed)

4. Discussion

The purpose of this study was to analyse the effect of a long-term embedded, structured, and supported IPS instruction in solving authentic problems of different curricular disciplines undertaken by secondary students. To be more specific, the study aimed to determine the effect of instruction on the development of IPS skills and the improvement of the students' task performance. Frequencies of constituent skills on a pre- and post-test were calculated to measure differences between students who participated in the embedded IPS instruction and those who did not. In addition, the sub-skills performed were also analysed and compared. Our hypothesis was that students who participated in the long-term embedded IPS instruction to better solve problems on curricular contents would perform the IPS process and the accompanying constituent skills more adequately and intensively than students who did not participate in the instruction. Moreover, our study also aimed to verify the impact, if any, of improving the IPS skills and task performance on the students' learning results.

Regarding the constituent skills, the instruction might have a positive and significant effect on the skill 'defining the problem'. After attending the IPS instructional process, experimental students performed that skill more frequently. Research carried out by Brand-Gruwel et al. (2005) reveals that experts spend considerably more time on defining the problem than novices. Similarly it could be expected that 'more instructed (or experienced)' students also use more time to examine problem information (Wopereis et al., 2008). It could be remarked that the instructional process designed in this research supported extensively and thoroughly those IPS skills related with 'defining the problem' by means of driving questions to activate the prior knowledge and determine appropriate search terms, and worksheets to specify the information needed. According to Pejtersen and Fidel (1999), an adequate understanding of the problem is needed in order to perform an appropriate use of search terms. Thus, we can state that the IPS instruction designed in our study succeeded in promoting IPS when applied to the skill 'defining the problem'.

In addition, the results of our study also showed interesting differences between experimental and control groups as regards the constituent skills 'searching for information' and 'scanning and processing'. In the resolution of the IPS task, the proportion between the number of times performed on the skill 'searching for information' and 'scanning and processing' by each group in the post-test varied. Although both groups performed the skill 'scanning and processing information' more times than the skill 'searching for information', the proportion is higher (more than doubled) in the experimental group. This trend reveals that the students from the experimental group could search more efficiently, needed less attempts and so they could invest more effort in 'scanning and processing the information'. This is also reflected in the students' task performance, as discussed below.

As regards the sub-skills, the experimental group obtained significantly higher appropriateness scores in 'search terms' typed and 'selected results' from the SERP, in comparison with the control group during the post-test. The experimental group could search more efficiently and so could perform more frequently other important skills, such as 'defining the problem', 'scanning and processing information', or 'organizing and presenting' it. These results are in line with those reported by Monereo et al. (2000), who found that experts use more elaborate search terms and carry out more accurate selection of the results from a hit list. Furthermore, Ladbrook and Probert (2011) suggested that improving on deciding which sites to visit –in other words, on selecting results–, would not only increase efficiency but also effectiveness on their performance. In the same vein, Lazonder (2000) reported that experts perform in a better way the location of the site than novices. Students belonging to the experimental condition show a more expert web-searching pattern than the control group ones. These results show that the embedded, structured, and supported IPS instructional process might have a positive effect in developing skills related with 'searching for information'. During the resolution of the instructional Web-based tasks designed in this project, experimental group students were scaffolded to reflect on the search terms to type in order to find specific information and assess the results retrieved by them. Besides, scaffolds in the form of prompts and messages guided students explicitly to reflect and evaluate the results retrieved by the SERP before selecting them.

Furthermore, the IPS instruction also might have a positive effect on experimental students' task performance. Statistically, control group students scored significantly lower results than the experimental group. This is in line with findings by Gerjets et al. (2011), whose study showed that stimulating learners to engage in web-search skills could improve their web-search performance. In our view, all the scaffolds provided during the instruction and especially those related to 'scanning and processing the information' might help students to construct knowledge in a more efficient way. The IPS instructional process consisted in designing both specific worksheets to help students analyse the general content of a website and prompts to encourage students to read and process its information.

Finally, the results of the study described in this paper coincide with previous findings by Brand-Gruwel et al. (2009), who pointed out that the constituent skills and sub-skills involved in IPS are highly related among them. For example, defining the problem in depth could have contributed to search the information better, and to select results from a SERP in an appropriate way (and, consequently, to make less attempts in the skill 'searching for information'); specifying the search terms could have made it easier to select an appropriate result; scanning and processing the information carefully could have enabled a better answer to the assignment. These relationships were verified statistically in our study. Furthermore, the close relationship between the variables of the process (constituent skills and sub-skills) and the variables of the product (task performance) might lead to conclude that the students' abilities of 'search terms' typed and the 'selected results' from a SERP are influential factors among search strategies to their task performance on the Web, as stated by Tu et al. (2008) and Gerjets et al. (2011). Therefore, an important part in IPS instruction is helping students' search skills.

The present study is an attempt to give an insight into the design and implementation of long-term and well-integrated IPS instruction in Secondary Education curriculum. Our results showed the effectiveness of the long-term embedded, structured, and supported instruction to develop students' IPS skills and task performance. However, our results must be interpreted carefully due to the following three limitations. First, the sample considered for this study –20 participants in each condition– might be a slightly limited segment to generalize the results to a wider segment; on the other hand, those results outline an encouraging path in the field of instructional design in IPS. Second, we are aware that the results presented in this study are not exclusively accountable to the IPS instructional process designed, implemented and assessed in our study, but also to another key educational variable that was not recorded in our research –the teacher. Further studies could then take teachers into consideration as human scaffolds in orchestration with other kind of scaffolds (Kim & Hannafin, 2011), as teachers may guide students to take advantage of the technology scaffolds embedded the instructional process. Teacher guidance may better help the development of students' skills and task performance in everyday classroom settings (Crawford, 2000; Zhao & Frank, 2003). Third, another interesting issue that could have received more attention in our study is the fact that experimental students worked in pairs during all the instructional process. This variable was not analysed in our study but it could be in futures studies, due to the considerable incidence of the collaborative work in the improvement of IPS skills (Lazonder, 2005; Okada & Simon, 1997; Teasley, 1995).

Despite the above limitations, our study showed the potential in developing students' IPS skills through the design of an embedded, structured, and supported IPS instruction. We claim that this kind of educational intervention might contribute to coaching secondary students into digital competences that may allow them an adequate use of the information present on the Internet.

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* * *

The fourth research study will analyse in a more qualitative and in-depth way by means of a multi-case study the differences among students who participated and did not participate in the embedded IPS instruction. This last study will be presented in the next chapter in order to close the empirical part of this dissertation.

Chapter 8. Information-problem solving patterns and sequences of secondary students in classrooms: a multi-case study (Study 4)

The Internet has become one of the most important information sources in students' personal and academic life. In addition, the Web is receiving increased attention in education because of their potential to support new forms of learning. However, this new kind of learning implies the development of a set of abilities such as searching and tackling information from the Internet to find solutions of a problem – *Information-problem solving* (IPS). The main objectives of this study[25] are the following: first of all, to select representative cases to illustrate different kinds of IPS processes; second, to provide detailed and qualitative accounts of how secondary students solve an IPS task; and third, to identify the IPS skills, sub-skills, and regulation activities that have more incidence in students' ability to solve a problem using digital information on the Web.

In-depth analyses of quantitative and qualitative data of a multi-case study allowed us to identify distinctive patterns and sequences of students. Furthermore, IPS skills ('defining the problem' and 'search for information'), sub-skills ('specifying

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search terms' and 'selecting results from a SERP'), and regulation activities (orientation on the task, monitoring, and testing) were identified as key abilities which have more incidence in students to solve IPS tasks to learn curricular contents at school, and which should be taken into consideration in teaching.

1. Introduction

The World Wide Web (WWW) has become one of the most important information sources in students' lives –secondary students use Internet widely for both schools assignments and leisure. In addition, the WWW is receiving increased attention in education because of its potential to support new forms of learning. However, although learning in such dynamic learning environments is much more engaging, it is also much more challenging (Kuiper, Volman, & Terwel, 2009), and a set of abilities as searching and tackling information from the Internet to find solutions of a problem are needed. As discussed in Chapter 2 of this dissertation, this set of abilities has been called *Information-problem solving* (IPS). Since the Internet is an extensive source of information, IPS skills and regulation activities are necessary in order to be successful in Web-based learning (Brand-Gruwel et al., 2005). Nevertheless, contemporary cognitive and educational research has shown that most students have difficulty in performing IPS skills and regulating their learning spontaneously (Lazonder & Rouet, 2008; Wood, 2009), as was thoroughly explained in Chapter 2 and analysed in Study 2 (Chapter 5) in this dissertation.

In this context, school is the institution that has the mission to provide citizens of the necessary competences to become active and critical individuals in our Information Society. Competences related to the Information and Communication Technologies –in particular IPS cognitive processes (skills and regulation activities)– are needed to be developed by students, in order that they could better use the information of the WWW.

The objectives of this last study of this dissertation are, on the one hand, to select representative cases to illustrate different kinds of IPS processes, in order to provide detailed and qualitative accounts of how secondary students solve an IPS task; and, on the other hand, to identify the IPS skills, sub-skills, and regulation activities that have more incidence in students' ability to solve a problem using digital information on the Web.

In this section, we will relate the concept of IPS with the concept of regulation, and afterwards we will formulate the objectives which guide this study.

1.1. Information-problem solving skills and regulation activities

As explained in previous chapters of this dissertation, the concept of IPS combines the skills needed to access and use information found on the Internet. According to the model proposed by Brand-Gruwel et al. (2005), it is assumed that students need to master the following constituent skills: ‘defining the information problem’, ‘searching for information’, ‘scanning information’, ‘processing information’, and ‘organizing and presenting information’. Furthermore, each skill can be subdivided in several sub-skills; for instance, ‘defining the information problem’ involves the sub-skills of reading the task (assignment) or activating prior knowledge, and ‘searching for information’ requires the sub-skills of specify search terms or select a result from SERP.

In addition, to be successful in IPS, a set of regulation activities is also required during the execution of all those skills. Regulatory aspects such as orientation, monitoring, steering, and evaluation, play an important role for the coordination of the IPS process.

‘Orientation’ includes the analysis of the task, and the task performance. ‘Steering’ is aimed at making decisions about what activities have to be performed; steering occurs on a macro level (i.e., to plan what to do) and on a micro level (i.e., to decide what to do next). ‘Monitoring’ the process means that someone keeps ‘an eye on task performance’ (Brand-Gruwel et al., 2005) or ‘a finger on the pulse’ (de Jong & Simmons, 1988) during the IPS process. Finally, ‘testing’ is focused on evaluating process and product; it is formative when this is done during the resolution of the task, and it is summative in case both process and product are evaluated at the end of the IPS process.

Studies on IPS have found that when attempting to solve IPS tasks and regulate their learning process, students predominantly use ineffective strategies (Azevedo et al., 2004). Particularly, secondary students use information that can solve their information-problem without thinking about the purpose of a website (Fidel et al., 1999) and they hardly evaluate information results and information sources (Walraven et al., 2009).

As regards regulation activities, secondary students did not feel the need to plan a search or to check whether their planning was adequate (Fidel et al., 1999; Lyons et al., 1997). However, they did check their spelling in URLs and search terms and were aware of the fact that spelling can influence the results of a search (Fidel et al., 1999). In addition, non-strategic searchers are less successful and do not regulate their search process (MaKinster et al., 2002; Monereo et al., 2000). Brand-Gruwel et al. (2005) stated that experts monitored and steered their process more often than novices. According to Walraven et al. (2008), the quality of the IPS process is influenced by regulation –students become better searchers when they orientate, monitor, steer, and test during their IPS process.

1.2. Research objectives

Previous studies have examined how students use the WWW to solve IPS tasks (i.e., Brand-Gruwel et al, 2005; 2009), as well as the difficulties that students find while solving IPS tasks (i.e., Britt & Aglinskas, 2002; Goldman, 2011; Lorenzen, 2002; Wallace et al., 2000). Some studies, for instance, have focused on how students assess the information or sources found on the Internet (i.e., Walraven et al., 2009). Others have described searching patterns of students while using the Web at school (Makinster et al., 2002). This study extends previous work in that it focuses on in-depth descriptions and analyses on how the IPS skills can have an incidence on students' ability to successfully solve a problem using digital information.

The goals of this research were to gain a more detailed understanding of the key IPS abilities *sine qua non* students' lack of success in their learning through the Internet. The following objectives guide this study:

(1) To select representative cases to illustrate different kinds of IPS processes.

(2) To provide detailed and qualitative accounts of how secondary students solve an IPS task.

(3) To identify the IPS skills, sub-skills, and regulation activities that have more incidence in students' ability to solve a problem using digital information on the Web.

2. Method

2.1. Participants, design, procedure and materials

Participants. Six students participated in this multi-case study. They were students of the 7th and 8th grade (13-15 year-olds), in Secondary Education. The students belonged to the sample of Study 3 (Chapter 7).

Design. The six participants of this study were strategically selected to represent specific IPS processes, in order to be described and analysed in-depth. Three participants unsuccessfully solved an IPS task, and three successfully solved it. Furthermore, the three unsuccessful cases differed among them, and the same happened with the successful ones. Thus, multi-case study analysis may be richer, due to the reasons explained in Chapter 4 (section 2.2.). Finally, it can be noticed that the unsuccessful cases had not received previous instruction in IPS skills and regulation at school, and the successful ones did received such instruction.

Procedure. Participants performed an IPS task as a test. They solved it individually during 50 minutes approximately. Considering the conclusions explained in Study 1 (Chapter 5 of this dissertation), the IPS task was performed in the real context of the classroom, as a curricular learning activity, in order to ensure ecological validity (Wopereis & van Merriënboer, 2011).

Materials. As widely described in previous chapters (in particular, in Chapter 4, Section 4), the IPS task was divided into two main parts. In part 1, participants were engaged in completing a concept map to collect information about planet Mars. In part 2, participants had to accomplish three steps: (2.1) explain the conditions a planet must fulfil to make life possible on it, (2.2) describe the favourable and unfavourable conditions of Mars, and (2.3) write a final essay that would answer the question of whether it would be possible to install a human colony on Mars.

In this study, the analysis is focussed in step 2.1., also called a “sub-task”, in which students were engaged to explain, using Internet information, the conditions a planet must fulfil to make life possible on it.

2.2. Data analysis procedure

The IPS task performed by each participant was logged in by the logfile technique, screen-capture software called CamStudio 2.0 in an attempt to record all the actions executed on the computer screen. For each logfile obtained, we examined in-depth sub-task 2.1 (that is one of the questions of the IPS task –‘explaining, using information from the WWW, the conditions a planet must fulfil to make life possible on it’).

On the basis of the coding scheme constructed and presented in Chapter 4 (Section 5.1), the sub-task was carefully analysed considering the constituent skills, the sub-skills, and the regulation activities. The **constituent skills** considered were the following: (1) ‘Defining the problem’, when the student was analysing the demand at the task webpage, and s/he was not typing anything on it, (2) ‘Searching for Information’, when the student was accessing a search engine, typing search terms on it, or selecting results from a SERP, (3) ‘Scanning and processing information’, when the computer screen showed a website, in which the student wss dealing with its information, and (4) ‘Organizing and presenting information’, when the student was typing an answer at the task webpage. The **sub-skills** considered in this study were the following: search terms, selected results, and processing information. In addition, **regulation activities** consisted of: orientation on the task, monitoring-steering, and testing.

Figure 26 shows the constituent skills, sub-skills, and regulation activities considered in this study, and gives an overview of the interrelation between them –the two way arrows in the figure represent the iterative direction among skills, which are not performed in a linear way (Eisenberg & Berkowitz, 1990; Wopereis et al., 2008). Furthermore, each variable are described below.

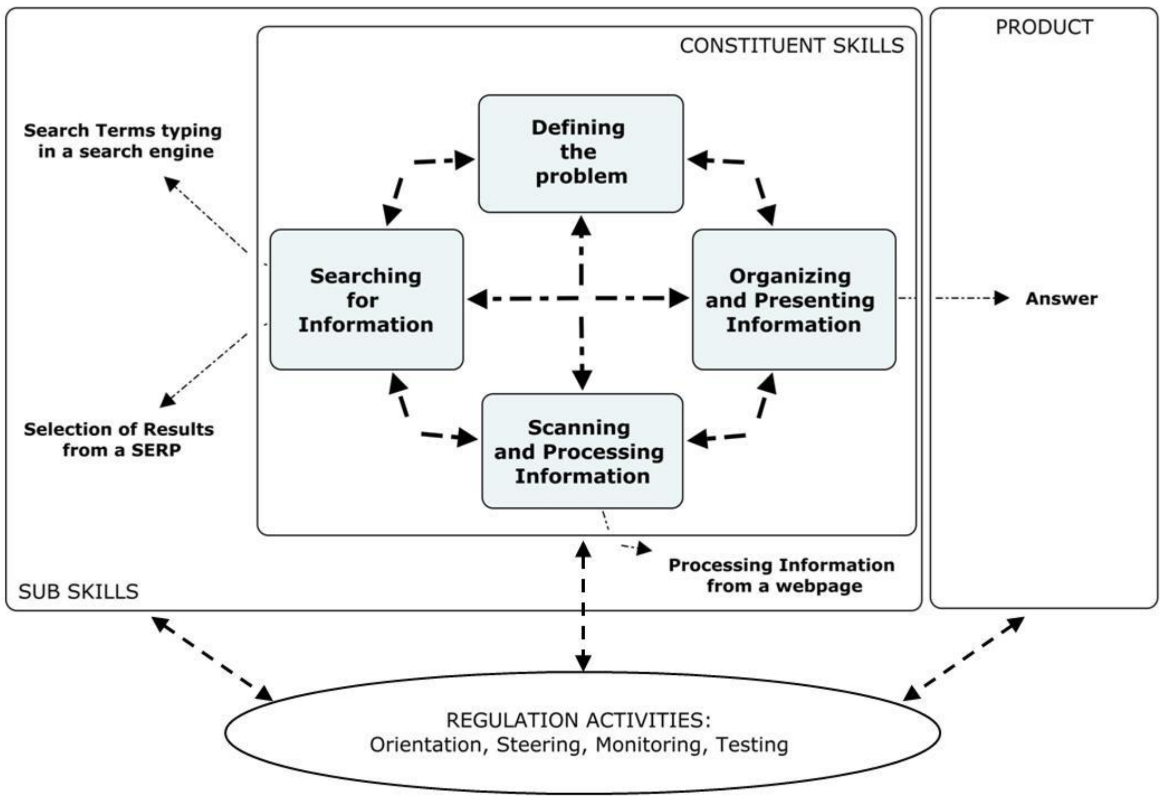

Figure 26. Constituent skills, sub-skills, and regulation activities considered in this study

In order to give insight about the IPS process and product performed by the students while solving an information-problem, we will elaborate for each student, the following: (1) **IPS patterns**, (2) **IPS sequences**, and (3) **in-depth descriptions** of the IPS process and product.

(1) An **IPS pattern** is composed by the quantitative measurements of the following variables: time spent on the sub-task resolution, number of skills performed, appropriateness scores of the sub-skills (search terms, selected results, and processing of the information), and the answer's correctness. Table 32 shows the quantitative variables which outline the IPS patterns.

Table 32. Variables considered for the analysis of each student's IPS pattern

Variable	Description	Classification
Time spent	Minutes that student spent solving the question.	Numerical
Number of **skills** performed	Number of total times that student performed the constituent skills to solve the question.	Numerical
Sub-skill: **Search Terms** (appropria-teness score)	The appropriateness of each search-term typed in a search engine scored as 'appropriate' (ST+) or 'inappropriate' (ST-). This appropriateness considered their context and their demand. In addition, an appropriateness score was calculated as a percentage considering the number of all the search terms typed and the number of the appropriate search terms (see Studies 2 and 3, Chapters 6 and 7).	Low <25% Medium = 25-75% High >75%
Sub-skill: **Selected Results** (appropria-teness score)	Each result that was selected from a SERP by each participant scored as 'appropriate' (SR+) when it was both usable and reliable, or as 'inappropriate' (SR-) when it was not usable or unreliable. Again, an appropriateness score was calculated as a percentage considering the number of the total selected results and the number of the appropriate ones (see Studies 2 and 3, Chapters 6 and 7).	Low <25% Medium = 25-75% High >75%
Sub-skill: **Processing of Information** (appropria-teness score)	Each webpage consulted by the participants was analysed to determine whether it contained useful information to solve the question. Each time that student closed a webpage in which there was not (more) useful information scored as 'appropriate' (PI+), and each time that student closed a webpage which contained useful information, scored as 'inappropriate' (PI-). In addition, each time that a student took useful information from the webpage scored as PI+, and non-useful information scored as PI-. An appropriateness score was calculated as a percentage considering the number of total number of PI and the number of PI+.	Low <25% Medium = 25-75% High >75%
Answer correctness	Each student answer scored as 'correct' (A+) or 'incorrect' (A-).	Low = correct High = incorrect

Two raters familiar with the IPS task, the materials and the coding scheme, scored the variables of one student (17% of the total). Interrater reliability yielded a Cohen's kappa higher than .80. One rater scored the students' remaining variables.

The quantitative classification of each variable per student will allow us to identify distinctive IPS patterns, which will help us to compare and describe the different IPS sequences performed by the students.

(2) An **IPS sequence** is a graphical illustration of each step given by the participant during the resolution of the sub-task. This sequence shows the actions performed over time, the order in which each one was performed, the switches between

the skills, the times that each sub-skill was performed and whether it was appropriate or not, and the total time of the execution of the sub-task.

(3) The complementation of the IPS patterns and the IPS sequences will allow us to better **describe, analyse, and understand the IPS process and product** performed by each participant. These in-depth descriptions will contain new elements (in addition to the elements which come from the IPS patterns and the IPS sequences), which will come from the context analyses of each IPS process. For instance, these new elements are the regulation activities, which are more interpretative and context-based. Table 33 shows the regulation activities, which are not included in Table 32 because they are not quantified but interpreted by the context.

Table 33. Regulation activities considered for the analysis of each student's IPS process

Variable	Description
Orientation on the task	Number of times that student consulted the demand in a deep way (defined the problem while solving the task).
Monitoring-steering	Number of times that a student refined the search terms. Number of times that student corrected mistakes while typing a set of search terms or an answer. Number of times a student closed opened and unuseful windows to better manage the useful ones.
Testing	Number of times that a student deleted or (re)typed the search terms after typing them. Number of times that student deleted or corrected mistakes after typing a sentence or a text in the answer.

3. Results

The main objectives of this study are to provide a **detailed and qualitative account** of how secondary students solve an IPS task, and to identify the IPS **skills**, **sub-skills,** and **regulation activities** that have **more incidence** in students' ability to solve a problem using digital information on the Web. In this section, firstly, we present a summary of each participant as regards their variables' measurement in a quantitative way (**IPS pattern**). Secondly, we graphically illustrate and thoroughly analyse the sequence performed by each participant (**IPS sequence**). These detailed descriptions of students' experiences will facilitate an ongoing discussion about the IPS abilities that have a great incidence in solving information-problems while using the Internet to learn in secondary classrooms.

Table 34 shows the variables which summarize the IPS patterns of each participant of this study. The names of the participants are fictitious in order to protect their identity. The first three participants (Axel, Pam, and Peter) performed unsuccessful sub-tasks, due to the incorrectness of their answers. In contrast, the last three participants (Ashley, Myriam, and Moses) performed successful sub-tasks.

Table 34. IPS patterns of the participants during sub-task 2.1

Partici-pants	Time spent	Number of skills performed	Appro-priateness of ST	Appro-priateness of SR	Appro-priateness of PI	Answer correc-tness
Axel	12:57	12	-	/	+	-
Pam	6:50	19	-	-	/	-
Peter	7:47	11	/	/	/	-
Ashley	8:05	10	-	/	+	+
Myriam	8:00	20	/	+	+	+
Moses	6:04	18	+	+	+	+

Legend:
ST (search terms), SR (selected results), PI (processing of the information);
+ (high), / (medium), - (low).

In order to give better understanding of the IPS processes performed by the participants, we draw graphical illustrations and describe them in a more qualitative way. Figure 27 shows the IPS sequences performed by each participant during the sub-task 2.1. The numbers in each illustration indicates the order in which every skill was performed. The reader is suggested to follow the numbered arrows in the illustration together with the descriptions below, to better understand the sequence. The first numbers in the illustration have been highlighted for easier access.

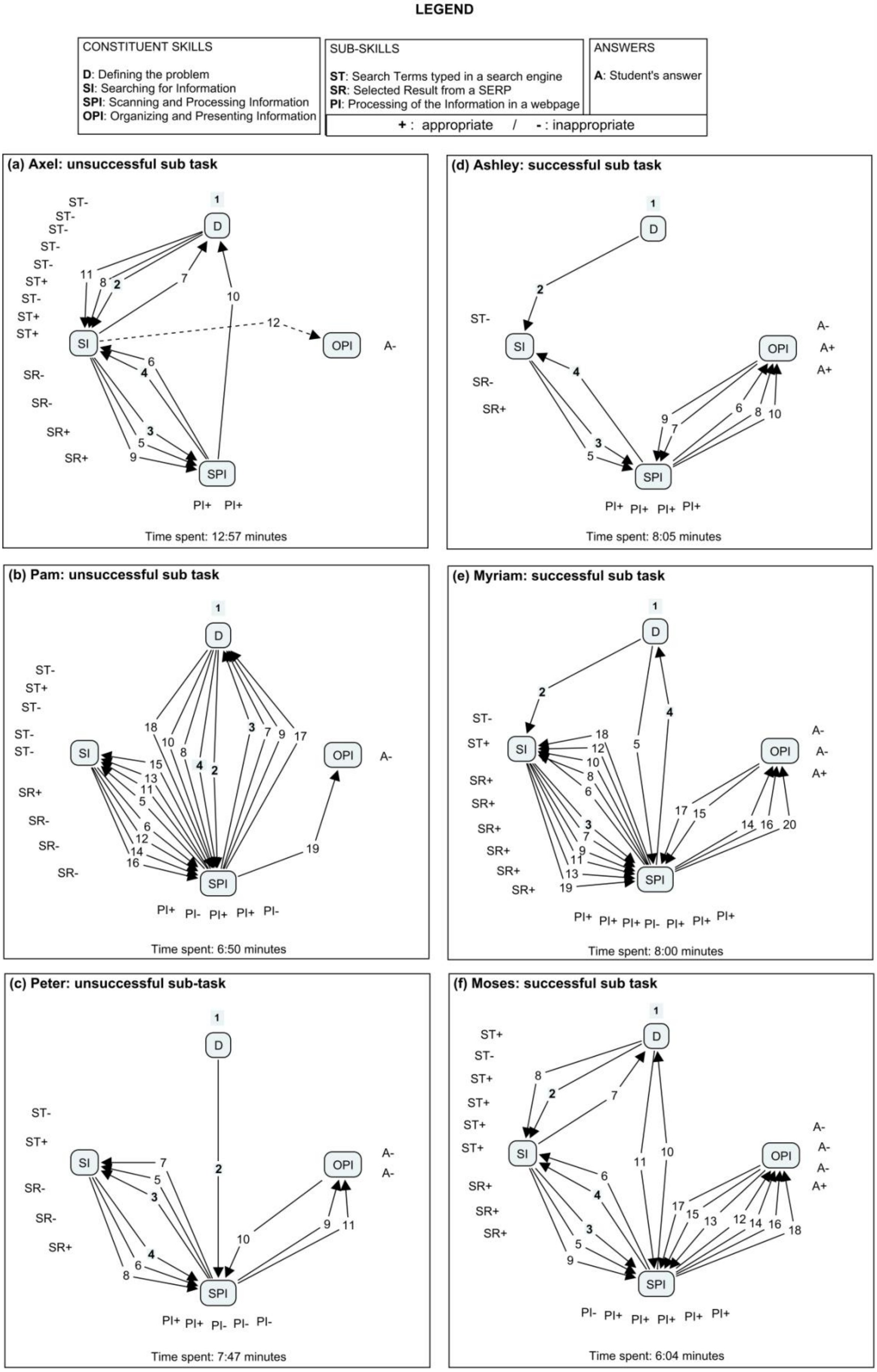

Figure 27. IPS sequences performed by each participant during sub-task 2.1

3.1. Axel

Axel, unsuccessful sub-task (Figure 27a)

1. "Defining the problem" ("D"). When Axel opened sub-task 2.1 for the first time, he scrolled the webpage down till the bottom. Then, he positioned his mouse on the paragraph of the instructions to solve the problem: what are the necessary conditions that a planet should have for life to be held in it. This was the first skill that Axel performed in this sub-task.

2. "Searching for information" ("SI"). Next, he started a new constituent skill by clicking an available link (to access "Google"). He typed in the search terms "BBC world", by correcting his typing mistakes before submitting them. Those search terms were inappropriate (ST-) on account of the demand and the kind of webpage queried. A SERP was retrieved, and Axel selected the second result: "BBC world". This selection of result was also inappropriate (SR-).

3. "Scanning and processing the information" ("SPI"). Then, the webpage "BBC world" opened up. Axel scrolled down through the page, which contained advertisements and news about different topics. There was not useful information to solve the task, neither was there any search engine in that webpage. Axel clicked on the "back" button (PI+).

4. "Searching for information" ("SI"). The SERP opened up again, and Axel typed in the search terms "life on Mars" –by correcting his mistakes while typing–, quite inappropriately (ST-) because the search terms should have revolved around the issue of life on any planet, not exclusively in Mars. After scrolling down and up through the results, Axel selected the result "Life on Mars... really?" (SR-).

5. "Scanning and processing the information" ("SPI"). The webpage "Life on Mars... really?" opened up. Axel scrolled down the page and kept his mouse on it. The information found in that page was about current research on Mars with technical and scientific language, so it did not contain useful information to solve the task. Thus, Axel clicked on the "back" button (PI+).

6. "Searching for information" ("SI"). Again, the SERP opened up, and the student typed in a new set of search terms in the search engine: "conditions to live", –by

correcting his mistakes while typing–, inappropriate (ST-). When the SERP was retrieved, he scrolled down through the results, which were irrelevant. Then he scrolled up and changed his search terms, by typing in "what is needed to live" (ST-). A new SERP was retrieved and Axel scrolled down through the results.

7. "Defining the problem" ("D"). Then, Axel positioned his mouse for a few seconds on the screen that displayed the problem to be solved.

8. "Searching for information" ("SI"). Axel came back to the SERP and went on scrolling down to the bottom of the page. The results were irrelevant. Thus, he scrolled up and typed in new search terms: "exhobiology", which were incorrect due to wrong spelling (ST-). Immediately, the link "did you mean exobiology" was available and he clicked on it (ST+). When the SERP appeared, he slowly scrolled down and then selected the result "Exobiology-Wikipedia", that was appropriate (SR+) in terms of both topicality and reliability.

9. "Scanning and processing the information" ("SPI"). The webpage "Exobiology-Wikipedia" was available and Axel positioned his mouse on several links, which were the categories to be chosen. He selected the result "astrobiology" (SR+) and a new page was retrieved. He positioned his mouse on the first paragraph, in which the concept astrobiology was explained. However, the webpage did not contain any useful information to solve his task.

10. "Defining the problem" ("D"). Then, Axel accessed the page where the problem was explained.

11. "Searching for information" ("SI"). Afterwards, the student came back to the search engine and typed in "exophobia" (ST-). Reasonably, the SERP lacked useful results. Then, Axel typed in the search terms "exobiology" (ST+). When the new SERP was retrieved, the student scrolled down through the results, which were in Catalan. He selected one of them: "The origin of life and astrobiology", from the University of Barcelona (SR+). However, it could not be retrieved due to technical problems. Then, he changed the URL www.google.com to www.google.es, probably to obtain Spanish results. Thus, he typed in again "exobiology" (ST+) and a new SERP was retrieved. Axel scrolled down and up several times, but he did not select any result, despite the fact that they were appropriate.

12. "Organizing and presenting information" ("OPI"). Finally, the student accessed the task webpage and typed in an answer to the question. His answer was about the basic things that a planet should have to hold life in it: water, oxygen and

atmosphere, and Axel corrected his spelling mistakes while typing. However, the answer was incomplete (A-), and had not been found in any of the pages visited during his web-search. After typing in this answer, the student finished task 2.1.

* * *

To sum up this sub-task, Axel performed 12 constituent skills and spent a total time of 12:57 minutes. After several attempts, he came up with appropriate search terms and appropriate selections of results. Axel did an appropriate processing of the information of the webpages that he opened up, but it should be interpreted with caution because there were only two occasions to process the information and, besides, the content of the pages were so irrelevant that it was obvious that the student was not able to find useful information, and he had to close the pages sooner or later. As can be appreciated in Table 34, this student's pattern shows a low level of ST, middle of SR and 'high' of PI. Axel did not find information to solve his problem adequately, despite the long time devoted trying it. On the one hand, despite the fact of consulting the problem twice during the task resolution, he did it in an inadequate way. As a result, he typed in search terms wrongly (see numbers 7 and 8, and numbers 10 and 11). On the other hand, the many attempts in specifying the search terms typed in a search engine made him spend so much time in doing it, that he lacked time to perform other important skills, as 'scanning and processing the information' and 'organizing and presenting information'. In other words, if he had specified better search terms in less attempts, he would have had more time to explore more webpages to find useful information and solve the task correctly.

3.2. Pam

Pam: unsuccessful sub-task (Figure 27b)

1. "D". The first time that Pam opened this sub-task, she positioned the mouse on the paragraph containing the instructions of the problem to be solved. Then she scrolled down the page almost to the end.

2. “SPI”. After that, Pam clicked on a minimized window of a webpage from Wikipedia that she had opened up during a previous task. She then positioned the mouse at the bottom of the page and then on a paragraph about climate change.

3. “D”. She clicked on the minimized window of the Web task containing the instructions of the assignment, and scrolled it up and down.

4. “SPI”. The student accessed the previous webpage again and in the end discarded it by clicking on the “back” button (PI+).

5. “SI”. Thus, the Google engine appeared. She typed in the following search terms: “conditions that should have a planet to warrant life”, with serious spelling mistakes (ST-), despite the fact of correcting some spelling mistakes while typing. Consequently, no results were retrieved. Pam typed in a new search term: “life on the planets” (ST+). When the SERP appeared, she selected the first one: “planets and life” (SR+).

6. “SPI”. On the new webpage “planets and life”, Pam followed with the mouse some sentences from the first paragraph, which dealt with the possibility of life in extra-solar planets.

7. “D”. Then, she maximized the page where the assignment was, for just one second.

8. “SPI”. She returned to the webpage and positioned the mouse at the bottom, where information about the instrument to detect life in other planets could be read.

9. “D”. She consulted the assignment again for a short time.

10. “SPI”. Then, she went back to the webpage, and clicked on the “back” button, discarding useful information to solve the task (PI-).

11. “SI”. The previous SERP appeared. Although there were appropriate results in the SERP, she typed in other search terms in the search engine: “conditions that a planet should have to allow life”, with serious spelling mistakes (ST-). Despite the mistakes, one result was still retrieved. It was about a calendar and about violence and, despite that, she selected it (SR-).

12. “SPI”. A webpage appeared. The student scrolled down the page. It was about gender violence and was difficult to read, due to the presence of uncommon symbols. She discarded the page by clicking on the “back” button (PI+).

13. “SI”. Back to the search engine, Pam typed in new search terms: “mars 100%” (ST-). When the SERP appeared, she positioned the mouse on some of the results retrieved. Without selecting any of them, she typed in the terms “life to mars”

(ST-). She immediately selected one of the first results, entitled “Mars”, by Solarviews (SR-).

14. “SPI”. The new page about Mars appeared. She scrolled the page down and positioned the mouse on a paragraph about some features of Mars. The student scrolled again through a table about more characteristics of Mars, and kept her mouse on a paragraph about the same content. Finally, she clicked on the “back” button (PI+).

15. “SI”. When the SERP appeared, she selected the following result: “life on Mars?” (SR-).

16. “SPI”. On the new webpage, she followed some sentences from the first paragraphs, whose content was about Mars and possibilities of life on it.

17. “D”. Then, Pam opened the page of the assignment for three seconds.

18. “SPI”. Again, she returned to the webpage. Once there, she selected some paragraphs about characteristics that allow life on Mars, and copied them.

19. “OPI”. Finally, she opened the page of the assignment and she pasted what she had copied previously. The answer was not correct, because the question was about the necessary conditions that a planet should have to warrant life, and the answer was specifically about the planet Mars.

* * *

To summarize this sub-task performed by Pam, she performed 19 constituent skills and spent 6:50 minutes in answering the question. Although she attempted several times to type in search terms and to select results, very few of them were appropriate. Her pattern showed low levels of ST and SR, and a middle level of PI. As a consequence of those behaviours, Pam was not able neither find useful information nor give a good answer to the question of this sub task. In the same way that Axel, Pam consulted the assignment in a wrong way, and as a result she typed inappropriate search terms and selected an inadequate result (see numbers 3 and 5 in the sequence), and processed wrongly the information (see numbers 7, 8, 9 and 10 in the sequence). Although Pam performed the ST better than Axel, she spent a lot of time trying to select an appropriate result from a SERP, which hindered her from finding a good website that provided appropriate information to solve the task.

3.3. Peter

Peter: unsuccessful sub-task (Figure 27c)

1. “D”. Peter started this sub-task by positioning his mouse at the bottom of the assignment page. Then, he enlarged it to its full capacity. Finally, he positioned the mouse on the paragraphs of the instructions to solve the problem.

2. “SPI”. Then, he clicked on a minimized window, and a webpage appeared. Its content was about the canyons of Mars, and so he clicked on the “back” button (PI+).

3. “SI”. In the Google engine, he typed in the search term: “planets”, which was too general (ST-). A SERP was retrieved and he positioned the mouse on the third result. Then, he selected a result called “planets”, whose description indicated that it was about planets and their factual features (SR-).

4. “SPI”. The page about planets was opened and he quickly scrolled the page down till the end. There were some factual features and descriptions about some planets and the Sun. As it was not useful information to solve the task, he clicked on the “back” button (PI+).

5. “SI”. Thus, the Google engine appeared. He kept his mouse on the search terms typed before, and then he typed in the following ones: “life in a planet” (ST+). Consequently, a new SERP was retrieved. He positioned the mouse on some results, and finally he selected the first one: “Association to take care of a living planet”, about ecology, poverty and rights, by an organization (SR-).

6. “SPI”. The new page was retrieved and Peter scrolled down it slowly. It contained an agenda about several events to be carried out by the association. He kept his mouse on one of the paragraphs and then scrolled the page up till the top. Finally, he clicked on the “back” button (PI+).

7. “SI”. At the SERP, he selected another result: “Aliens”, about how life could be possible on a planet, by the educational government (SR+).

8. “SPI”. At the new webpage, Peter scrolled down through an image of the Earth, and he followed some sentences from the first paragraph, whose content was about the human capability to adapt itself to hostile conditions on the Earth. After that, he kept his mouse on that paragraph. Although that content was not appropriate to answer the question given in the assignment, he selected and copied it, by clicking on the “right button”, and then selecting “copy”.

9. “OPI”. At the assignment page, he pasted that information, and so the answer was incorrect (A-).

10. “SPI”. Immediately, Peter accessed the webpage again and scrolled down on the following paragraphs, which dealt with some discoveries by astronomers in the past, as well as with the possibility of life in the universe. After following a sentence with his mouse about the possibility of life outside the Earth, Peter selected and copied it.

11. “OPI”. He opened the page of the assignment and pasted it, immediately after his previously pasted paragraph. Then, he typed in that this could make you consider the possibility of life on Mars. Although he corrected some mistakes while typing his answer, this was not an appropriate answer to the problem of the assignment. After that, he scrolled the page down and finished the task.

* * *

As a summary of the sub-task performed by Peter, he performed 11 skills altogether and spent 7:47 minutes on them. His pattern levels are middle in ST, SR and PI. He was not able to find useful information and, as a consequence, he did not solve the problem appropriately. Although Peter came with adequate ST and SR, he spent some time attempting it. Maybe if he had consulted the demand, he would be able to do that in less time. Furthermore, he lacked in PI while consulting the webpages; thus, he did not find useful and reliable information to satisfactorily solve the problem.

3.4. Ashley

Ashley: successful sub-task (Figure 27d)

1. "D". Ashley started this sub-task by scrolling down through the page of the assignment and scrolling up to the paragraphs of the instructions to solve the problem. She kept her mouse on that page for a few seconds.

2. "SI". Then, she clicked on a minimized window and a SERP was opened. She typed in the search terms "life on Mars" (ST-), which showed a slight lack of understanding of the problem to be solved, despite the fact that she corrected some spelling mistakes while typing. When the SERP was retrieved, she clicked on the first result: "life on Mars" by an audiovisual producer (SR-).

3. "SPI". When the webpage was opened, Ashley positioned her mouse on a list of links of TV channels. Immediately, she clicked on the "back" button (PI+).

4. "SI". Just like in the previous SERP, she kept her mouse on the results for a few seconds, until she finally selected one of them: "Mars exploration: general outline", from NASA (SR+). Although this result dealt with Mars, its description and URL showed that its content was introduced from a wider approach, for what could be expected as useful information to satisfactorily solve the task.

5. "SPI". On the new page, she scrolled down to the first paragraphs, whose content was about Mars and its features. Again, Ashley scrolled down to the following section, where information about Mars and life on the planets could be read. Then, the student followed with her mouse some sentences of one of those paragraphs (PI+).

6. "OPI". After that, Ashley clicked on the minimized window where the problem was to be solved and typed in that water is a critical element that allows life in a planet. Although the answer was correct and she continually corrected her mistakes while typing and after typing the sentence, it was insufficient to completely answer the question (A-).

7. "SPI". She went back to the webpage and stayed on the same paragraph for a few seconds (PI+).

8. "OPI". Then, she accessed again the task webpage and added the information about other important elements for life: oxygen, atmosphere and vegetables, with some

examples and explanations (A+). She kept correcting her typing mistakes while typing her answer.

9. "SPI". Ashley had another look at the webpage (PI+).

10. "OPI". Finally, she completed the answer by finishing a sentence about the importance of those conditions for life (A+), again by correcting her mistakes while typing her answer.

* * *

As a summary of this sub-task, this student performed 10 constituent skills and spent 8:05 minutes on them. In Table 34, the levels that characterize Ashley's pattern are: low in ST, middle in SR and high in PI. Although her initial search terms and selected results were inappropriate, she could select an appropriate result from the SERP, which allowed her to find useful information. As she appropriately processed the information on the webpages consulted, she was able locate an adequate webpage and a useful piece of information to solve the problem satisfactorily. Contrary to the previous students' sequences, Ashley devoted little time to the search skill (to ST and SR); thus, she had plenty of time to scan and process the information as well as to organize and present it. In addition, Ashley monitored her process of organizing and presenting the information found in the Internet, by correcting her typing in a constant way as well as changing a sentence after writing it, which reveals monitoring and testing activities in this student.

3.5. Myriam

Myriam: successful sub-task (Figure 27e)

1. "D". When Myriam opened sub-task 2.1, she positioned her mouse on the paragraph containing the instructions of the problem to be solved. Then she scrolled down the page to position her mouse in the blank space of the answer.

2. "SI". After that, Myriam opened a new webpage and, thus, a Google engine appeared. She typed in the following search terms: "conditions to live", which were too general (ST-). When the SERP appeared, she positioned the mouse on some of the results, and she finally selected an appropriate result: "Life-Wikipedia" (SR+)

3. "SPI". Coming back to the webpage, Myriam slowly scrolled down the page. It was about life in general. Then, she scrolled up it.

4. "D". Just for a few seconds, she accessed the task webpage to consult the problem to be solved.

5. "SPI". She returned to the webpage and positioned the mouse on a paragraph about biological organisms. There was not useful information to solve the task. Myriam clicked on the "back" button, discarding the page (PI+).

6. "SI". The previous SERP appeared. She typed in other search terms in the search engine: "conditions for life in a planet" (ST+), by refining the search terms typed previously. A new SERP was retrieved and Myriam positioned her mouse on the first results. She, finally, selected one of them, about conditions for life, from NASA (SR+).

7. "SPI". At the new webpage, the student scrolled a set of advertisements and then she followed with the mouse some sentences from the first paragraph, which dealt with some life conditions found on Mars, especially water. She positioned the mouse on the other following paragraphs and finally discarded the page. This information will be used later in the answer given by Myriam. This is why the processing of the information executed on this webpage is considered as appropriate (PI+).

8. "SI". In the same SERP, she slowly scrolled down the results and selected a new result about a discovered planet with possibilities for life, from EFE (SR+).

9. "SPI". A webpage appeared. The student scrolled down the page. It was about factual features of a planet, which were not useful for the task. So that, Myriam discarded the page by clicking on the "back" button (PI+).

10. "SI". At the SERP, she kept her mouse on the results for a few seconds, until she finally selected one of them: "A planet fulfils all the requirements to allow life", from a scientific journal (SR+).

11. "SPI". When the webpage was opened, Myriam positioned her mouse on the text. Although the page contained useful information, she immediately clicked on the "back" button (PI-).

12. "SI". Back to the SERP, Myriam scrolled up the results and selected the first one, which dealt with a discovered planet similar to the Earth, from a reliable journal (SR+).

13. "SPI". When the webpage was opened, Myriam positioned her mouse on its title, about the water found on that planet (PI+).

14. “OPI”. Immediately, she went to the Web task and typed “water”. Although the answer was correct, it was insufficient to completely answer the whole question (A-).

15. “SPI”. On the webpage, she slowly scrolled down the first paragraphs, whose content was about water and temperature. She positioned her mouse on those paragraphs following some sentences and words (PI+).

16. “OPI”. Afterwards, Myriam accessed the task webpage and typed in there that the temperature should be similar to the Earth’s, which was still incomplete (A-), despite the fact of correcting a mistake typed while writing.

17. “SPI”. Then, she went back to the webpage, and continued scrolling the page till the end, in which there was not anything else. Thus, Myriam clicked on the “back” button (PI+).

18. “SI”. Again at the SERP, she positioned the mouse on the next results, but finally she scrolled up till the search engine to type in “planetary conditions for life” (ST+). A new SERP was retrieved and she positioned the mouse on the third result, about life conditions of planets. Then, he selected it (SR+).

19. “SPI”. She scrolled down and followed with the mouse some sentences from the first paragraphs, which dealt with some life conditions such as the sun’s distance and atmosphere (PI+).

20. “OPI”. Finally, Myriam typed in the task the condition of the atmosphere (A+). Afterwards, she finished this task.

* * *

To sum up this sub-task performed by Myriam, she performed 20 constituent skills and spent 8:00 minutes to solve it. Table 34 shows the levels of the variables performed by Myriam: middle in ST, and high in SR and PI. Although she failed in her first attempt to type search terms, she improved them. The consult of the demand done during this task resolution was a critical factor which improved the other skills (see number 4 in the sequence). Immediately after consulting the demand, Myriam was able to identify the non useful information on the webpage (see number 5 in the sequence), to specify an appropriate ST –by refining the search term typed previously–, and to select an appropriate SR (see number 6 in the sequence). Furthermore, the fact that Myriam consulted several appropriate webpages and that she performed an adequate processing of its information, allowed collecting and integrating different pieces of information that enriched her answer to satisfactorily solve the task.

3.6. Moses

Moses: successful sub-task (Figure 27f)

1. "D". When Moses opened sub-task 2.1 for the first time, he positioned the mouse on the paragraph containing the instructions of the problem. Then, he scrolled down the page to the end, and afterwards he again positioned his mouse on the paragraph of the instructions. Finally, he selected and copied the key word 'the exobiology'.

2. "SI". Then, he clicked on a minimized window and a SERP appeared. He pasted in the search engine the key word copied from the assignment: "the exobiology" (ST+). A new SERP was retrieved and he positioned the mouse on the first and second result. Although they were relevant, Moses preferred to change the search terms in the search engine, by refining the previous ones. This time, he typed "the exobiology conditions", but he kept "the exobiology" in Catalan and "conditions" in Spanish (ST-). Immediately, he noted that, and changed "the exobiology" into Spanish (ST+), which was another refinement of search terms. The SERP appeared, and he selected the first result, relevant and reliable, after being positioned in it for some seconds (SR+).

3. "SPI". The page about exobiology was opened and Moses kept his mouse in the first paragraphs, in which the information was not very relevant. He scrolled down the page and kept his mouse in the following paragraph, which was not relevant as well. He repeated these actions for four times. However, at the third one, the information contained in one of the paragraphs was useful to answer the question of the assignment, but he did not notice it. Finally, he discarded the webpage (PI-).

4. "SI". Thus, the Google engine appeared. He kept his mouse on the search terms typed before, and then he typed in the following ones, by refining the previous ones: "conditions of a planet" (ST+). Consequently, a new SERP was retrieved. He positioned his mouse on some results, but he did not select any of them due to their inappropriateness. Again, he scrolled up to the search terms. This time he refined them again by typing in "conditions of life planet" (ST+). After positioning his mouse in the first ones, he selected the fourth result, "Life-Wikipedia" (SR+).

5. “SPI”. The new webpage was retrieved and Moses positioned the mouse on its paragraphs and slowly scrolled down it. The webpage contained information about life in general; however, it did not show useful information to satisfactory solve the task. Finally, the student discarded the page (PI+).

6. “SI”. Moses returned again to the SERP, and he selected another result: “Gaia hypotheses” (SR+), which was opened in a new window.

7. “D”. He then, opened the page of the assignment for seven seconds.

8. “SI”. Afterwards, he typed in the search engine the following search terms: “exobiology” (ST+). When the SERP appeared, Moses selected the third result, “exobiology or astrobiology” (SR+).

9. “SPI”. Backing to the webpage, Moses positioned his mouse in the first paragraph, which contained useful information about conditions of life on a planet. Then, he slowly scrolled down through the text.

10. “D”. Once more, he consulted the demand to better define the problem to be solved.

11. “SPI”. On the webpage, he positioned his mouse in the first paragraph, which did not contain useful information about conditions. Then, he slowly scrolled down through the text, and positioned in another paragraph that did contain relevant information to solve the task (PI+).

12. “OPI”. On the assignment page, he typed in that liquid is a critical element that allows life on a planet. Although the answer was correct and he corrected some mistakes while typing, it was still insufficient to completely answer the question (A-).

13. “SPI”. When Moses went to access the webpage again, he accessed one of the several webpages previously opened. Immediately, he closed all of them, except the one in which he had found relevant information. In there, he moved the mouse over the paragraph which dealt with some useful information (PI+).

14. “OPI”. Then, he accessed the answer page again and added the information about other important elements for life. Although he corrected his mistakes during and after typing the answer and the answer was being improved, it was still incomplete (A-).

15. “SPI”. Moses had yet another look at the webpage (PI+).

16. “OPI”. This time, in the Web task, he structured the text written (A-).

17. “SPI”. He went back to the webpage and stayed on the same paragraph for a few seconds (PI+).

18. "OPI". Finally, he completed his answer by adding conditions to allow life on a planet (A+). While typing, he kept correcting his mistakes.

* * *

As a summary of the sub-task executed by Moses, he performed 18 skills and spent 6:04 minutes to satisfactorily solve the task. Moses reached high levels in ST, SR and PI (Table 34). It is worth remarking that the consult of the demand during the task resolution helped him to adequately specify ST and SR (see numbers 7 and 8 in the sequence), and to appropriately perform the PI (see numbers 10 and 11). In addition, Moses' sequence was highlighted by his dedication to assess the results retrieved by a SERP, by spending time in doing that. As a result, he only accessed the necessary webpages, which allowed him to focus in its content to adequately solve the question in a little period of time. As Myriam did, saving time in the skill "search for information" permitted him to "scan and process the information" on the webpages as well as "organizing and presenting" it as a solution for the problem of the task. Moses also demonstrated regulation activities, such as: (1) refining most of the search terms he typed, (2) closing the non useful webpages previously opened, and (3) correcting mistakes during and after writing the answer.

In the following section, we compare the students' patterns and sequences to highlight important IPS skills, sub-skills and regulation activities that have a great incidence in the ability to solve the problem using digital information on the Web.

4. Discussion

The results presented above show that the constituent skills, sub-skills, and regulation activities involved in IPS are highly interrelated –students frequently switch between skills, and the result accomplished by one sub-skill is often the input for another sub-skill, so that the coordination between these abilities is very important, as other studies pointed out (i.e., Brand-Gruwel et al., 2005; Kuiper et al., 2008; Lazonder & Rouet, 2008). In the following paragraphs, we discuss each constituent skill and sub-skill, as well as observe the influence of the regulation activities involved thorough the students' IPS processes.

As regards the constituent skill "**defining the problem**", the qualitative analysis made by illustrating and describing each IPS sequence help us to understand the value of this skill. First of all, it can be divided into "defining the problem for the first time" at the beginning of the task, and "consulting the problem" during the task. The later acquires regulation significance and has been considered as "**orientation on the task**" (e.g., Brand-Gruwel et al., 2005). Our students' IPS sequences showed good examples of consulting the problem in a superficial way or in an in-depth way. Axel and Pam consulted the problem in a superficial way during their task resolution, and so they had a lack of insight in what was demanded to solve the problem. As a consequence, they did not improve the ST, SR, or PI. In contrast, Myriam and Moses consulted the problem in a deeper way; and as a result they clearly were able to specify better ST, to select more appropriate results and to find useful information or discarded non useful information.

Consulting the problem in a deep way during the task resolution –or, in other words, being orientated on the task– was a key IPS skill that improved other constituent skills and sub-skills, and therefore impacted the successful resolution of the problem using digital information on the Web, as other studies also found (Brand-Gruwel et al., 2009; Pejtersen & Fidel, 1999).

Regarding the constituent skill "**search for information**", and its sub-skills ST and SR, we can remark on the importance of spending the necessary time in the essential moments. When students did not dedicate enough to appropriately specify the ST, the result was a waste of time trying to select an (inexistent most the time) appropriate result from a SERP. In addition, when students did not spend time assessing the results according to both their usability and reliability before selecting a result, the consequence was a set of going-and-going back and forth between the SERP and the websites, which also signified a waste of time. All of this happened to Axel, Pam, and Peter. In contrast, when students devoted time to specify ST and to assess and reflect before selecting a result, they had more time for other important processes (i.e., Ashley, Myriam, and Moses). This time saved is usually needed later to perform other constituent skills as "scanning and processing the information" or "organizing and presenting the information", as we pointed out in our previous study (Chapter 7 of this dissertation). Students' abilities of ST and SR are, indeed, influential factors to satisfactorily solve a problem (Gerjets et al., 2011).

In this regard, the regulation activity has played a critical role in specifying ST. In particular, the refinement of ST when the previous ones did not produce good results enough has helped students to overcome the difficulties of specifying appropriate ST and, in consequence, to find useful search results in the SERP. An example of this can be found in Myriam and Moses' sequences. When Myriam typed the ST for the first time, she failed; however, she refined them and got appropriate ST, which retrieved a good list of hits in the SERP. Moses refined his ST for four times; he typed a ST and then he consulted the search results on the SERP; afterwards he refined the previous ST and again assessed the results. Finally, the refinement process led him to obtain a better SERP in order to select an appropriate website in which he could extract useful information to answer the task. This process can be identified by a regulation activity, particularly, as "**monitoring**" (de Jong & Simmons, 1988; Moore, 1995).

As regards the skill "**scanning and processing information**", the qualitative analyses of this study gave us insight to identify different levels of doing that. Scanning a wegpage consists in getting an overview and judging the information on usability and reliability in order to decide whether or not the information must be linked to the given problem and can be trustworthy, whereas processing the information refers to deep reading, elaborating on the content, and assessing the processed information (Brand-Gruwel et al., 2005). Our students –particularly Ashley, Myriam, and Moses– showed good skills in scanning and processing information, revealed by the indicators that they took advantage of the useful and reliable information from the webpages visited and they also discarded the non useful information. They also chose appropriate web links, which reveals a deep level of comprehension during the skill of "scanning and processing the information" (Salmerón, Cañas, Kintsch, & Fajardo, 2005).

We also observed an indicator of regulation activities concerning the management of the webpages visited, scanned, and processed. Moses worked with several webpages at the same time –he kept them opened in different windows. When he finally found an appropriate webpage and he realized that he sometimes failed in opening the correct window to process its information, he immediately closed the unnecessary windows. This action shows a "**monitoring**" behaviour that definitively made more efficient and easy his process of consulting the information in the selected webpage. Garner and Alexander (1987) and Land and Green (2000) called this kind of process as "knowledge about different cognitive demands of different learning tasks" as well as "procedural knowledge of strategies to employ when unsuccessful".

In reference to the skill "**organizing and presenting information**", the students who went back and forth between the webpage and the task page to give an answer, obtained a high-quality answer in their task resolution. This was the case of Ashley, Myriam, and Moses, which started their answer and then they completed and improved it by consulting the same webpage or other pages. In contrast, Axel and Pam performed this skill only once, and their answers were incorrect or incomplete, which probably could be solved by contrasting the information found with new information, as the other students did.

Regulation activities can also be identified in some students' IPS sequences as regards the constituent skill "organizing and presenting information". For instance, Alex, Ashley, and Moses kept correcting their mistakes while typing their answer. This behaviour could be an indicator of "**monitoring**" because it could reveal "the finger on the pulse" expressed by de Jong & Simmons (1988). In addition, Ashley and Moses showed actions that also reveal regulation activities, in particular, "**testing**"; they changed and improved some sentences after having typed them, which means a good behaviour of re-reading their typed answers. Monitoring and testing helped students – i.e., Ashley and Moses– to detect spelling, grammatical, or content problems in their answers, as well as to enhance them (Hill, 1999; Stenberg, 1986).

* * *

After the in-depth analyses presented in this chapter, it can be concluded that every skill, sub-skill, and regulation activity is important to successfully solve an IPS task, due to the fact that everyone accomplishes a specific mission in the whole IPS process.

However, our qualitative analyses of detailed students' IPS process and product revealed that we could highlight critical abilities *sine qua non* it is hard to successfully solve a task. We consider as key skills, the following two: (1) **defining the problem** in a deep way, which allows students guiding their web-search and IPS execution, and (2) **searching for information**, which is a key skill to deal with digital information on the Internet.

Belonging to the later, the sub-skills that we consider as critical after our in-depth qualitative analyses are the following two: (1) '**specifying appropriate search terms**' in order to obtain the most accurate SERP in a short time, and (2) '**selecting appropriate results from a SERP**' to avoid accessing unnecessary websites. The adequate execution of these two sub-skills are crucial because it permits locating the necessary information in an adequate period of time; otherwise time will be needed in order to accomplish the other required skills to satisfactorily solve the information-problem, for instance: "scanning and processing the information" at the selected website or "organizing and presenting the information" as an answer to the IPS task.

Furthermore, we also consider as key regulation activities, the following three: (1) **orientation** on the task, which implies a deep consultation of the problem requirements thorough the execution of the IPS task to be able to adjust the actions needed, (2) **monitoring**, as a continuous supervision of the IPS task execution (particularly, refinement of search terms typed, correcting what is being typed, and closing unnecessary windows), and (3) **testing** the search terms before entering them or the text written as an answer, in order to decide whether it is solving the initial problem or contrarily some information is still needed. Regulation activities may improve other IPS abilities, as the constituent skills and sub-skills, and therefore they may influence the quality of the IPS processes and products of the students.

Chapter 9. General discussion and conclusions

The overarching objectives of this dissertation were, on the one hand, to **identify and describe the main challenges that secondary students should overcome to solve IPS** more efficiently. On the other hand, to study the **effect of embedded, structured, and supported instruction** on IPS cognitive processes and task performance. And finally, we intended to draw **conclusions and educational implications** for the scholar practice to help Secondary Students to enhance their IPS processes while learning curricular contents at school.

In order to accomplish these main purposes, four studies were carried out in this dissertation. In this section, first, we will summarise the main conclusions of each study. Secondly, we will discuss the educational implications that can be outlined from these four studies. Thirdly, we will draw the main conclusions of our research dissertation. Finally, we will outline the contributions of our work, some limitations of the research process, as well as the further research lines that may be continued.

9.1. Conclusions of each study

The first specific objective formulated in our research dissertation was **to compare different techniques to analyse the cognitive processes involved in IPS: "logfiles", "eye-movements", and "cued retrospective reports based on eye-movements".**

This objective was accomplished by the first study presented in this dissertation (Chapter 5). The analyses of the three techniques of this study led us to distinguish the different features of each technique. Concerning the data that can be retrieved, the *logfile technique* (LOG) collects all the overt actions made in the computer screen, which give insight about cognitive processes, while the *eye-movement technique* (EYE) collects the attentional processes, which give more fine grained information about the areas which were paid attention to, and so they also give insight about cognitive processes. Finally, *cued-retrospective reports technique* (CRR) collects utterances on cognitive processes and regulation activities. Whereas LOG can retrieve all the actions made in the computer screen and EYE is able to retrieve all the attentional processes performed, CRR cannot retrieve all the actions, attentional processes performed, cognitive processes or regulation activities.

The analyses of each technique and the comparison among techniques guided us to affirm that, on the one hand, each of them can give a **distinctive contribution** into the understanding of the IPS task, and, on the other hand, **the different features and affordances** of each technique and the distinct kind of information that each one can retrieve, are critical factors in deciding **which evaluation technique to use** in a research study. In addition, the situational circumstances and the evaluation goals or research questions also should be considered to choose one technique or another.

Considering both the conclusions extracted from this first study and the circumstances and research objectives of the following three studies, the technique used in was the logfile technique.

The second objective of our dissertation was the next one: **To provide detailed analyses of the challenges that secondary students face while solving an information task in their everyday classrooms, regarding their IPS process (constituent skills and sub-skills) and product (answers given and essays written by students)**.

Study 2 (Chapter 6) was devoted to exploring this issue. The quantitative and qualitative detailed analyses showed that the secondary students analysed faced several **challenges** in the development of an efficient IPS process (both in constituent skills and sub-skills) and in order to give a product as a result of the resolution of the problem. Particularly, specific challenges were found in the execution of the constituent skill "**search for information**". In this way, students faced several difficulties when executing the sub-skills that belong to this constituent skill, which are (1) **typing appropriate search terms** and (2) **selecting reliable and useful results** from a SERP ('search engine results page'), which make it easier or hinders the process of solving digital tasks.

Another important objective was: **To analyse the correlations between the IPS process followed to solve a problem using Web information, and the product obtained as a result of the resolution of that problem**.

Study 2 and Study 3 corroborated the same conclusion: variables related to **IPS process highly, statistically correlate with variables related to the product**. Furthermore, variables of the process were also related among them, which may mean that each constituent skill and sub-skill is necessary to be considered in order to warrant more successful problem solving behaviours. This conclusion advises that the enhancement of the constituent skills and sub-skills lead to an improvement of the solution of the IPS task. In particular, the students' abilities of 'search terms' typed and the 'selected results' from a SERP are influential factors among search strategies to their task performance on the Web. Therefore, an important part in IPS instruction is helping students' search skills.

The next objective was the following one: **To draw inferences about the educational intervention needed by students to develop efficient IPS while using the Web to learn curricular contents at school**.

Considering the conclusions of the previous objectives as well as the theoretical and methodological contributions analysed in previous Chapters (2 and 3), we proposed the design of an instructional process based on the following three key instructional principles:

(1) **Embedding** the IPS skills in curricular activities, in a meaningful and real context –classroom– spanning a long period of time, and for learning different curricular contents using Web information across the curriculum, with the purpose of facilitating both the development and the transfer of the IPS process and product to other contexts.

(2) **Structuring** the students' problem solving to guide them through the whole process of the resolution of the information-problem, to warrant the accomplishment of all the steps needed to successfully solve that problem, by means of providing a layer of structure between the student and the information source –the WWW.

(3) **Supporting** the student's problem resolution with specific scaffolds in each IPS constituent skill and sub-skill needed to tackle information-problems and in constructing the final product. The scaffolds could be embedded in the whole learning task, adapted to the different kinds of students and tasks, and should gradually lose intensity as the instructional process progresses.

The next specific objective was **to analyse the differences between students who participated in an embedded IPS instruction and students who did not participate, regarding the development of IPS skills and sub-skills during the resolution of an IPS task**.

Research study 3 (Chapter 7) accomplished this objective by a quasi-experimental study in secondary classrooms. Frequencies of constituent skills on a pre- and post-test were calculated to measure differences between students who participated in the embedded IPS instruction and those who did not. In addition, the sub-skills performed were also analysed and compared. Regarding the constituent skills, the instruction might have had a positive and significant effect on the skill '**defining the**

problem'. After attending the IPS instructional process, experimental students performed that skill more frequently, which revealed a more expert pattern. The IPS instruction supported extensively and thoroughly the IPS skills related with the definition of the problem. Thus, we can state that the IPS instruction designed succeeded in promoting this IPS constituent skill.

As regards the constituent skills 'searching for information' and 'scanning and processing the information', the proportion between the number of times those skills were performed by each group in the post-test revealed that the **students from the experimental group searched more efficiently**, needed less attempts and so they could invest more effort in 'scanning and processing the information'. This point was corroborated by the results of the sub-skills related to the skill '**searching for information**'. The experimental group obtained significantly higher appropriateness scores in 'search terms' typed and 'selected results' from the SERP, in comparison with the control group during the post-test.

The results of that study showed that the IPS instructional process might also have a positive effect in developing skills related with 'searching for information'. During the resolution of the instructional Web-based activities designed in this project, experimental group students were scaffolded to reflect on the search terms to type in, as well as to evaluate the results retrieved by the SERP before selecting them.

Therefore, the **embedded, structured and supported IPS instruction** had a **positive effect** on experimental students as regards the development of **IPS skills and sub-skills** during the resolution of an IPS task.

To gain more insight in studying the incidence of a well-designed IPS instruction, we carried out another objective **to analyse the differences between students who participated in an embedded IPS instruction and students who did not participate, and regarding the task performance** (in terms of results).

Study 3 (Chapter 7) also concluded that the IPS instruction also had a **positive effect on experimental students' task performance**. Statistically, control group students scored significantly lower results than the experimental group. The scaffolds and structure provided during the IPS instruction might have helped students to construct knowledge in a more efficient way.

Furthermore, a qualitative and quantitative analysis of the data of a multi-case study was carried out in order to give us more insight about the IPS cognitive processes developed by students. To construct the multi-case study, another specific objective formulated in our dissertation was to **select representative cases to illustrate different kinds of IPS processes**.

This objective was carried out in Study 4 (Chapter 8). The six participants of this study were strategically selected (from the sample of the previous study) to represent specific IPS processes, in order to be described and analysed in-depth. Three participants unsuccessfully solved an IPS task, and three successfully solved it. Furthermore, the three unsuccessful cases differed between them in terms of the manner of executing IPS skills and sub-skills, and the same happened with the successful ones. Thus, the multi-case study conducted in this study was richer and provided useful data to accomplish the rest of the objectives.

After the selection of the representative cases, the next objective formulated was **to provide a detailed and qualitative account of how secondary students solve an IPS task**.

This Study 4 (Chapter 8) presented a summary of each participant as regards their variables' measurement in a quantitative way (IPS pattern). In addition, the resolution of the task of each student was also graphically illustrated (IPS sequence). The IPS patterns and the IPS sequences constructed by each student facilitated a detailed and qualitative analyses of how secondary students solve an IPS task in their classroom in order to identify the cognitive processes that have more incidence in student IPS processes (the following objective).

On the basis of the IPS patterns and sequences obtained from the previous objectives, the last specific objective formulated in this dissertation was the following one: **To identify the IPS skills, sub-skills and regulation activities that have more incidence in students' ability to solve a problem using digital information on the Web**.

From Study 4 (Chapter 8), it was concluded that every constituent skill, sub-skill and regulation activity is important to successfully solve an IPS task. However, the qualitative analyses of detailed students' processes revealed that we could highlight critical cognitive processes *sine qua non* it is hard to successfully solve a task. We considered as key skills, the following two: (1) **defining the problem**, and (2) **searching for information**, particularly the sub-skills '**specifying appropriate search terms**' and '**selecting appropriate results'** are crucial. Furthermore, we also considered as key regulation activities, the following three: (1) **orientation on the task**, (2) **monitoring**, and (3) **testing**. This study contributed in the ongoing discussion about the cognitive processes involved in IPS that have a great incidence in solving information-problems while using the Internet to learn in secondary classrooms.

9.2. Educational implications

Considering the contribution of the four studies to respond to the objectives of this dissertation, we will attempt to draw educational guidelines that can be useful for the design of scaffolds and instruction to develop IPS cognitive processes at school. We will tackle diverse points that are crucial for instructional design in IPS, from the insight given by our results: (a) embedded and structured instruction, (b) supported instruction by several educational agents, (c) orchestration between the agents that support instruction.

(a) The first point to consider is the importance of **embedded** instruction, to be consistent with the epistemology embodied in the learning environment (Hannafin, Land, & Oliver, 1999) and because the IPS cognitive processes might be acquired embedded within a relevant and meaningful context, as the scholar curriculum, not by means of isolated assignments (Kuiper et al., 2008). In addition, it is important to highlight that each cognitive process (skill, sub-skill, regulation activities), and task performance, are highly related, as we discussed and concluded in Studies 2, 3, and 4. Thus, it is difficult to enhance one specific process or skill isolated from the others. In contrast, an interesting and positive synergy may be obtained from the instruction that integrates every skill, sub-skill, and regulation activity as a whole IPS process.

Related with this assumption, a defined **structure** for the IPS instruction that guides students through the whole process of the resolution of the information-problem might help students to internalise all the steps –skills, sub-skills, and regulation activities– needed to successfully solve that problem, by means of providing a layer of structure between the student and the Internet (Segers & Verhoeven, 2009).

(b) Considering the context of school to support and develop IPS cognitive processes, several agents appear to influence the effectiveness of scaffolding (Kim & Hannafin, 2011), that can be summarized as technology and human scaffolds. **Technology scaffolds** refer to the many tools that have been developed to support learning and teaching in technology-rich classrooms (i.e., Demetriadis et al., 2008; Lindh & Holgersson, 2007; Sanchez, Encinas, Fernandez, & Sanchez, 2002). As an implication drawn by our quantitative and qualitative analyses, technological scaffolds could be provided within a whole learning IPS task and they should be displayed on screen at certain times in the learning process in order to support each skill, sub-skill, and regulation activity needed to successfully accomplish the IPS task. Those scaffolds could be provided by means of questions, worksheets, prompts, pop-up messages, and templates. As another critical consideration, scaffolds should gradually lose intensity during the instructional process progress, in order to help students to internalize their IPS skills and regulation activities, otherwise scaffolds would not be efficient (Oliver & Hannafin, 2001).

In addition, **human scaffolds** are other important agents to support IPS skills and regulation activities to solve information-problems while learning curricular contents. Human scaffolds are teachers, peers, and other educators (such as: parents, family, equals, etc.); however, in this dissertation, we focus on teachers and classmates, as they are present at school, where IPS instruction usually takes place (or should take place).

Teachers have been criticized by researchers for ignoring critical factors influencing technology use in everyday schools (Zhao & Frank, 2003) and have been considered as an important piece in IPS instruction for their attitude toward and experience with technologies, which are crucial for using within everyday classroom settings (Becker, 1998; Zhao & Frank, 2003). For instance, in Land and Zembal-Saul's (2003) study, a computer-based portfolio was designed to support reflection and articulation during project-based learning; however, scaffolds were not used constructively when teachers failed to notice when learners were not generating appropriate explanations.

Teachers who are engaged to help students' IPS abilities, should be aware of the key skills to be developed by students: defining the problem, searching for information –particularly, the sub-skills 'specifying appropriate search terms' and 'selecting appropriate results'–, as well as the regulation activities that enhance IPS task resolution: orientation on the task, monitoring, and testing. This implies that teachers should have the knowledge and the experience needed to solve information-problems, and it would be desirable that they know how to help their students to overcome their difficulties in IPS tasks, as has been reinforced by researchers such as, i.e, Bryan and Atwater (2002).

Nevertheless, some teachers tend to use technology scaffolds to supplement ongoing teaching approaches instead of contextualizing and integrating the scaffolds to facilitate students' IPS process (Cuban, 2001). Teachers and technology scaffolds ought to be well orchestrated and work in the same line, by supporting one another, as we will explain later.

Another important **human scaffold** present in the classrooms and "profitable" for instruction are the **students themselves**. Although research has yielded inconsistent findings regarding peer or group interactions in science classrooms (Kim & Hanaffin, 2011), working in pairs has been considered by researchers to be a key instructional variable which has contributed to improving sub-skills involved in the constituent skill 'defining the problem', such as 'formulating questions' and 'activating prior knowledge' (Walraven et al., 2008). Furthermore, peer interaction allows users to negotiate the suitability of search processes and strategies, and gives the opportunity for users to critically observe each other's actions, which may facilitate early detection and correction of potential mistakes (Lazonder, 2005; Okada & Simon, 1997). Making decisions together about what search terms should be typed in a search engine, or which result should be selected from a SERP could definitively be a help to foster specific thoughts and individual reasons, which could increase the critical ability of secondary students. In addition, this presence of reflective learning might allow the development of regulation activities, such as orientation, monitoring, and testing. According to Schwartz (1995), students that work in pairs are generally better able to apply problem-solving regulation strategies than students who work individually.

Nonetheless, several challenges have been identified when students work in pairs (Ge & Land, 2003; Barron, 2000). Hannafin et al. (2003) found that the most cited factors that influence the quality of interactions among peers are: 'cognitive load' and 'limited prior experience'. Thus, instructional design should take into account those factors when they include peer scaffolding.

(c) This assumption leads us to consider the third point of this general discussion: the **orchestration** needed between the several types of scaffold (Kim & Hanaffin, 2011). Orchestration means not only that each agent has to go in the same line as others –for instance, when the technology embedded scaffolds aims to support the critical thinking of students on selecting the results from a SERP, the teacher also should promote this kind of thinking. Orchestration also means that the challenges implied by one agent, should be compensated by the other agents –for instance, if peer interactions increase cognitive load of individuals when working in pairs, technology scaffolds could provide specific aids to reduce working memory load (Sweller, van Merriënboer, & Paas, 1998).

Another example of how agents can compensate other agents' challenges is the following. Teachers play multiple roles in inquiry classes, including situating instruction in authentic problems, grappling with data, collaborating with students and teachers, connecting students with the community, modelling the behaviours of a scientist, and fostering student ownership (Crawford, 2000); however, teachers have additional multiple roles in technology-enhanced classrooms, such as: designers, problem solvers, context analysts, coaches, and evaluators (Kim, Hannafin, Adams, & Bryan, 2004). In this context, technology scaffolds can adopt a crucial role by assuming –till such a point– some teachers' roles. For instance, a Web-based task might be structured, as described above, to guide the IPS process, so that the teacher can be dedicated to other necessary roles that technology is not able to assume.

Multiple types of scaffolding interact within everyday classroom contexts, and they had to be well-orchestrated in order to take full advantage of them, and as a consequence students can develop key IPS cognitive processes (skills, sub-skills, and regulation activities) in their regular classrooms, in order that they could improve their digital competences that may allow them a better use of the Web.

9.3. Main conclusions

The main conclusions that we may extract from the discussed conclusions drawn from each study and from the general discussion, are summarized in the following points:

- **Different techniques can give a valuable contribution to the understanding of the IPS cognitive processes**. They have different affordances and limitations, and each one can complement the others. The election of one or another technique to assess the IPS processes **will depend on the objectives and the design of the research**.

- The sole access to Internet does not warrant to students successfully solving the information-problem process. An information-problem solving process implies complex cognitive processes that are not instinctively acquired. Thus, they must be learnt as a **necessary** literacy –**the digital literacy**.

- Since, on the one hand, we are immersed in the Society of the Information and the Internet is the principal scene of this society, and, on the other hand, school has the mission of enabling students to become active and critical citizens, an **adequate IPS instruction in school is needed** in order to help students to develop their digital competences that may allow them an appropriate use of the WWW.

- Instruction in IPS can be designed in several ways. The instructional process designed by the group COnTIC, composed by a set of Web-based tasks, following the principles of embedded, structured and supported instruction, **have been effective in students of Secondary Educational classrooms** for improving critical IPS processes.

- **Scaffolds** that support IPS instruction should be carefully designed; human and technological-scaffolds should be **appropriately orchestrated**, in order to get the most out of their affordances.

9.4. Contributions, limitations, and open research lines

From our view, the research dissertation presented in this report, based on the purpose of describing the main challenges that students face in IPS, studying the effect of an embedded IPS instruction, and drawing conclusions and educational implications for the scholar practice, constitutes an important **contribution** to the study of IPS in the measure that gives psycho-pedagogical and methodological clues that are valuable for the study of the IPS processes as a part of the learning and teaching process at school.

First of all, **the analyses of the three techniques in the first study of our dissertation can be a valuable contribution for educational researchers, designers, and educators in practice**. On the one hand, the fact of being aware about the different features of each technique and the distinct kinds of information that each one can retrieve, are critical factors in deciding which evaluation technique has to be used in a research study, and how to complement one another. Indeed, it may be interesting to combine the data retrieved by the distinct techniques and triangulate them in order to obtain richer learner profiles, which may guide drawing up stronger educational implications and conclusions on instructional design.

On the other hand, the affordances of each technique may be taken into account to make educators easier to observe in detail the development of IPS cognitive processes in their students, in order to provide adequate, individual aids to overcome the detected difficulties. Maybe educators in practice cannot access eye-tracking equipment to observe the eye-movements of their pupils; however, they can use the logfile technique to unobtrusively watch the IPS process of their students and detect points to be enhanced, especially related to "search terms typing" or to "select results from a SERP" during an IPS task performed in the classroom. In addition, the cued-retrospective reports technique can be used by basing it "on their own logfiles" when an eye-tracker is not accessible. It may allow a better understanding of the cognitive processes involved in IPS.

Apart from the contribution for researchers and educators, the conclusions drawn in this first study about the distinctive affordances and features of each technique, they can be generalised to the analyses of cognitive processes involved in other kinds of tasks or environments, such as peer-to-peer interaction, collaborative learning, self-regulation learning, game-based learning, or others.

Another important contribution of this dissertation is the set of **conclusions about the evaluation of the embedded, structured, and supported IPS instruction**. These conclusions showed the potential in developing students' IPS processes through the design of such instruction. From our view, this kind of educational intervention might contribute to enhance students' digital competences which may allow them a better use of Web information and fully participate in our global knowledge world. The features of this kind of IPS, or some of them, can be also applied to other levels of education. They can be a good, profitable example for educators, designers, researchers, etc.

Furthermore, the **IPS patterns and sequences** showed in this dissertation, in particular in Study 4, can be a **good contribution to illustrate IPS processes** for students, as well as to compare them with each other in order to detect difficulties to be overcome, and also to detect models of expertise to be imitated.

In addition to these sets of contributions, it is important to have in mind the **limitations** of this study. On the one hand, the technique used to collect the data was the *logfile technique*, which may be a limitation for the reasons presented in Study 1 (Chapter 5). The main limitation found was the risk to over interpret the actions made by the participants. As this technique only captures the actions made on the screen, some actions can easily be misinterpreted. The election of this technique was due to the ecological validity and the unobtrusiveness of the technique.

On the other hand, another limitation of this study may be that the focus was mainly given to the IPS processes of the students. Nevertheless, other technological and human agents in the classroom (for instance, teacher or equals) and their orchestration were not directly taken into account in this study. The observation and analysis of these variables could have contributed with valuable information to a more grained assessment of their influence in the development of IPS processes in classrooms.

These limitations lead us to **open new lines of further research**. One of these lines refers to the techniques to be used to collect data and the advantages of complementation with other techniques. **A deeper analysis of cognitive processes** would be facilitated by the **complementary use of other techniques**, as eye-movements or cued-retrospective reports based on these eye-movements, as discussed in Study 1 (Chapter 5) and throughout this chapter.

In addition, we consider a key element the teacher as a human agent in the IPS instruction. As remarked above, the analysis of the **role of the teacher** could contribute to understanding the dynamics of the classrooms and to design new strategies of teaching and learning that involve information-problem solving (Crawford, 2000; Keys & Bryan, 2001; Nespor, 1987). As well, the orchestration between the several agents (technological, peer, and teacher), as discussed above, could be an important topic to enhance the design of valuable learning environments in classrooms.

In this regard, also the **whole educational community** is worth studying. IPS and interaction with information and communication technologies are also used (even in a more intensive way) outside of school. Parents, family members, (virtual) friends, and mass media are potential, influential factors in the use and attitude towards the use of the Internet as an information and communication tool (Cuban 2004).

Another interesting open line for research is about the **affordances** that **ICT** has and how it could be **profitable at school** for learning curricular contents. In this research dissertation, we mainly focussed in the analyses of the IPS processes executed by the students, and we considered the necessity of learning digital literacy as one of the reasons to include IPS instruction at school. Nonetheless, from our point of view, the other main reason to integrate the information and communication technologies at school is the vast affordances that they bring for learning (Coll & Monereo, 2010).

Web 2.0 and collaborative learning is another open line to research. We live in a wired, globalized world in which the WWW is one of the main action scenarios. This new world is changing constantly and the Web is also changing. It has morphed from static HTML pages where readers could tackle its information (the main focus of this dissertation) to interactive services, where visitors can create and post information. The Web is now a participatory, interactive place where we can create information collaboratively and share their knowledge. Therefore, the Web evolution towards Web 2.0 reflects deep changes in social, economical and cultural organisation. These changes require that young citizens acquire new cognitive abilities and develop new competences about how to use and take advantage of these affordances, especially to collaborate and learn together.

Finally, it is worth remembering that computers are not the sole way to access the Internet anymore. People can access it from different devices. "**Mobile learning**" (or "m-learning"), for instance, has been increasingly studied as a way of learning with mobile devices as a support in classrooms or outside of them. M-learning has been defined as any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies (O'Malley, Vavoula, Glew, Taylor, Sharples, & Lefrere, 2003, Tremblay, 2010). M-learning focuses on the mobility of the learner, interacting with portable technologies, and learning that reflects a focus on how society and its institutions can accommodate and support an increasingly mobile population. M-learning is convenient in that it is accessible from virtually anywhere, which reveals an increase in the ubiquitous opportunities for learning from the Internet in our society.

Capítulo 9. Discusión general y conclusiones

Los objetivos fundamentales de esta tesis eran, por un lado, **identificar y describir los principales retos** que tendrían que superar los alumnos de secundaria para poder resolver de manera eficiente una tarea IPS y, por otro lado, estudiar el **efecto de un proceso de instrucción integrada en el curriculum escolar, estructurada y apoyada** en los procesos cognitivos IPS. Y por último, pretendíamos extraer **conclusiones y consecuencias educacionales** para la práctica escolar y ayudar a los estudiantes de secundaria a mejorar sus procesos IPS aprendiendo al mismo tiempo contenidos curriculares en la escuela.

Para lograr estos propósitos principales, en esta tesis doctoral se han llevado a cabo cuatro estudios de investigación. En esta sección, en primer lugar, resumiremos las principales conclusiones de cada estudio. En segundo lugar, analizaremos las implicaciones educativas que se derivan del conjunto de estos cuatro estudios. En tercer lugar, extraeremos las conclusiones generales de nuestra tesis de investigación. Finalmente, esbozaremos las principales contribuciones de nuestro trabajo, algunas limitaciones del proceso de investigación, así como las líneas de investigación abiertas que podrían ser continuadas futuramente.

9.1. Conclusiones de cada estudio

El primer objetivo específico formulado en nuestra tesis de investigación fue **comparar diferentes técnicas para analizar los procesos cognitivos implicados en IPS: "logfiles", "eye-movements", and "cued retrospective reports based on own eye-movements"**.

Este objetivo fue ampliamente descrito en el primer estudio, presentado en el capítulo 5 de esta tesis. Los análisis de las tres técnicas de dicho estudio nos llevaron a distinguir las diferentes características de cada una de ellas. En cuanto al tipo de información que se puede obtener mediante cada una, podemos afirmar que la técnica "logfiles" (LOG) recopila todas las acciones realizadas por el usuario en la pantalla del ordenador, que dan una visión acerca de los procesos cognitivos, mientras que la técnica "eye-movements" (EYE) recoge los procesos atencionales, que dan información más fina sobre las zonas a las que el sujeto presta atención, obteniendo así una visión más aguda sobre los procesos cognitivos. Por último, la técnica "cued retrospective reports" (CRR) es capaz de extraer expresiones verbales sobre procesos cognitivos y en concreto sobre las actividades de regulación. Considerando que LOG puede recuperar todas las acciones realizadas en la pantalla del ordenador y EYE es capaz de obtener todos los procesos atencionales realizados, CRR no puede recuperar todas las acciones, procesos atencionales, procesos cognitivos o actividades de regulación, sino sólo algunos de ellos.

Los análisis de cada técnica y la comparación entre técnicas nos llevaron a afirmar que, por un lado, cada una de ellos puede aportar una **contribución distintiva** en la comprensión de la tarea IPS y, por otro lado, las **diferentes características y potencialidades** de cada técnica y el distinto tipo de información que se puede obtener por cada una, son factores clave en la decisión sobre **qué técnica de evaluación a utilizar** en un determinado estudio de investigación. Además, las circunstancias situacionales y los objetivos o preguntas de investigación también deben considerarse al elegir una u otra técnica. Teniendo en cuenta tanto las conclusiones extraídas de este primer estudio como las circunstancias y objetivos de la investigación de los siguientes tres estudios, la técnica utilizada en estos últimos fue la técnica "logfiles".

El segundo objetivo de nuestra tesis fue el siguiente: **proporcionar un análisis detallado acerca de los retos que enfrentan los alumnos y alumnas de secundaria al resolver una tarea de información en sus aulas, en relación al proceso IPS** (*skills* y *sub-skills*) **y al producto** (respuestas dadas).

El estudio 2 (capítulo 6) se dedicó a explorar esta cuestión. Los análisis detallados de tipo cuantitativo y cualitativo mostraron que los estudiantes de secundaria analizados enfrentan varios **retos** en el desarrollo de un proceso IPS eficaz (tanto en *skills* como en *sub-skills*) y en la elaboración de un producto como resultado de la resolución del problema. Particularmente, los retos específicos fueron encontrados en la ejecución de la *skill* "**búsqueda de información**". De esta manera, los estudiantes enfrentan varias dificultades al ejecutar las *sub-skills* que pertenecen a esta *skill* constituyente, que son (1) especificar **términos de búsqueda** apropiados y (2) **seleccionar resultados** fiables y útiles en una SERP (‘*search engine results page’*), y facilitan u obstaculizan enormemente el proceso de resolución de problemas con información digital.

Otro objetivo importante era: **analizar las correlaciones entre el proceso IPS seguido para resolver un problema utilizando la información de la Web y el producto obtenido como resultado de la resolución de ese problema**.

Los estudios 2 y 3 corroboraron la misma conclusión: **las variables relacionadas con el proceso IPS correlacionaron estadísticamente y de una manera clara con las variables relacionadas con el producto**. Además, las variables del proceso fueron también relacionadas entre ellas, lo cual significa que cada *skill* y *sub-skill* debe ser necesariamente considerada para que se pueda llevar a cabo un proceso de resolución de problemas con éxito. Esta conclusión también nos dice que la mejora de las *skills* y *sub-skills* conduce a una mejora de la solución de la tarea IPS. En particular, las *sub-skills* ‘términos de búsqueda’ y la ‘selección de resultados’ en una SERP son factores influyentes entre las estrategias de búsqueda para un adecuado desempeño de tareas con el uso de la Web. Por lo tanto, un núcleo importante en la instrucción IPS radica ayudar a los estudiantes a desarrollar sus habilidaes de búsqueda de información.

El siguiente objetivo era **extraer inferencias acerca de la intervención educativa necesaria para que los estudiantes puedan desarrollar tareas IPS eficientes** al utilizar la Web para aprender contenidos curriculares en sus aulas.

Teniendo en cuenta las conclusiones de los objetivos anteriores, así como las contribuciones teóricas y metodológicas analizadas en capítulos anteriores (2 y 3), propusimos el diseño de un proceso instruccional basado en los siguientes tres principios educativos clave:

(1) **Integración** del proceso IPS en actividades curriculares, en un contexto significativo y real –clase– que abarque un período de tiempo suficientemente largo y en el que se aprendan diferentes contenidos curriculares utilizando información de la Web a través del curriculum escolar, con el fin de facilitar el desarrollo y la transferencia del proceso y producto IPS a otros contextos.

(2) **Estructuración** de los problemas de los estudiantes para guiarlos a través de todo el proceso de la resolución del problema, justificando así la ejecución de todos los pasos necesarios para resolver con éxito dicho problema, por medio de proporcionar una estructura de base entre el estudiante y las fuentes de información de la WWW.

(3) **Apoyo** de la resolución de problemas con andamiaje específico en cada *skill* y *sub-skill* IPS necesarias para abordar los problemas y la construcción del producto final. Los andamios específicos podrían insertarse a lo largo de toda tarea, adaptarse a los distintos tipos de tareas y estudiantes, y gradualmente perder intensidad a medida que avanzase el proceso instruccional.

A continuación, otro objetivo específico era el siguiente: **analizar las diferencias entre los estudiantes que participaron en una instrucción IPS integrada y los que no participaron, en relación con el desarrollo de *skills* y *sub-skills* durante la resolución de una tarea IPS**.

El estudio 3 (capítulo 7) estuvo dedicado a la consecución de este objetivo mediante un estudio cuasi experimental en aulas de secundaria. Se calcularon las frecuencias de las *skills* de un pre-test y un post-test para medir las diferencias entre los estudiantes que participaron en la instrucción IPS y los que no. Además, también se analizaron y compararon las *sub-skills* llevadas a cabo por cada alumno y alumna. En cuanto a las *skills*, la instrucción podría haber tenido un efecto positivo y significativo en la '**definición del problema**'. Después de recibir el proceso instruccional IPS, los estudiantes del grupo experimental realizaban esta *skill* más frecuentemente, lo cual revelaba un patrón más cercano al de las personas expertas. La instrucción IPS tuvo una amplia y exhaustiva incidencia en las habilidades relacionadas con la definición del problema. Por lo tanto, podemos afirmar que la instrucción IPS diseñada tuvo éxito en la promoción de esta IPS *skill*.

En cuanto a las *skills* 'búsqueda de información' y 'escaneo y procesamiento de la información', la proporción entre el número de veces que se llevó a cabo en cada grupo en el post-test, reveló que **los estudiantes del grupo experimental buscaban de manera más eficaz**, necesitaban menos intentos de búsqueda y así podían invertir más esfuerzo en el 'escaneo y procesamiento de la información'. Este aspecto fue corroborado por los resultados de las *sub-skills* relacionadas con la '**búsqueda de la información**'. El grupo experimental obtuvo puntuaciones significativamente más altas en la adecuación de los "términos de búsqueda" introducidos en el motor de búsqueda y de la "selección de los resultados" de la SERP, en comparación con el grupo control durante el post-test.

Estos resultados llevaban a concluir también que el proceso instruccional IPS pudo tener un efecto positivo en el desarrollo de estas habilidades relacionadas con la búsqueda de información. Durante la resolución de las actividades instruccionales basadas en Web diseñadas en este proyecto, los estudiantes del grupo experimental fueron apoyados mediante un amplio andamiaje para que reflexionaran sobre los términos de búsqueda a escribir, así como para evaluar los resultados obtenidos en la SERP antes de seleccionarlos.

Por lo tanto, la instrucción IPS integrada, estructurada y apoyada tuvo un efecto positivo en los estudiantes del grupo experimental en relación con el desarrollo de *skills* y *sub-skills* durante la resolución de una tarea IPS

Para obtener más información en el estudio de la incidencia de una instrucción IPS bien diseñada, llevamos a cabo otro objetivo: **analizar las diferencias entre los estudiantes que participaron en la instrucción IPS integrada y los estudiantes que no participaron, en cuanto a su desempeño en la tarea** (en términos de resultados).

El mismo estudio 3 (capítulo 7) también llegó a la conclusión de que la instrucción IPS tuvo asimismo un **efecto positivo sobre el rendimiento en la tarea por parte de los estudiantes del grupo experimental**. Estadísticamente, los estudiantes del grupo control alcanzaron resultados significativamente menores que los del grupo experimental. El apoyo mediante andamiaje y la estructura seguida durante la instrucción IPS pudieron haber ayudado a los estudiantes a construir conocimiento de manera más eficiente.

Además, se llevo a cabo un análisis cualitativo y cuantitativo de los datos en un estudio multi-caso a fin de obtener más información acerca de los procesos cognitivos IPS desarrollados por los estudiantes. Para construir el estudio multi-caso, otro objetivo específico formulado en nuestra tesis fue **seleccionar casos representativos para ilustrar diferentes tipos de procesos IPS**.

Este objetivo se llevó a cabo en el estudio 4 (capítulo 8). Los seis participantes de este estudio fueron estratégicamente seleccionados (de la muestra del estudio anterior) para representar procesos específicos IPS, con el fin de ser descritos y analizados en profundidad. Tres participantes resolvieron una tarea IPS sin éxito, y los otros tres la resolvieron con éxito. Además, entre los tres primeros había diferencias en cuanto a la forma de ejecutar IPS *skills* y *sub-skills*, y lo mismo ocurría con los tres últimos. Así, el estudio multi-caso llevado a cabo en este estudio sería más rico y proporcionaría datos útiles para el desarrollo y la consecución del resto de los objetivos.

Después de la selección de los casos representativos, el siguiente paso era **ofrecer un análisis detallado y cualitativo sobre el proceso de resolución de los estudiantes de secundaria al resolver una tarea IPS**.

El mismo estudio 4 (capítulo 8) presentó un resumen de cada participante recogía la medida de sus variables de forma cuantitativa (patrón IPS). Además, la resolución de la tarea de cada estudiante fue ilustrada gráficamente (secuencia IPS). Los patrones y las secuencias IPS construídas de cada alumno y alumna facilitaron un análisis detallado y cualitativos sobre la resolución de una tarea IPS por parte de los participantes seleccionados, a fin de identificar los procesos cognitivos que tienen mayor incidencia en un proceso IPS (objetivo siguiente).

Sobre la base de los patrones y secuencias IPS obtenidas en el objetivo anterior, el último objetivo específico formulado en esta tesis fue **identificar las *skills, sub-skills* y actividades de regulación que tienen una mayor incidencia en la capacidad de los estudiantes para resolver problema mediante información digital**.

Desde el estudio 4 (capítulo 8), se concluyó que cada una de las *skills*, *sub-skills* y actividades de regulación es importante para resolver con éxito una tarea IPS. Sin embargo, los análisis cualitativos detallados de los procesos de los estudiantes revelaron que podríamos destacar procesos cognitivos clave *sine qua non* es difícil resolver con éxito una tarea IPS. Consideramos, pues, como *skills* clave las dos siguientes: (1) **definición del problema** y (2) **búsqueda de información**, particularmente las *sub-skills* 'especificación de los **términos de búsqueda** apropiados' y '**selección de resultados** adecuados'. Además, también consideramos como actividades de regulación clave, las tres siguientes: (1) **orientación en la tarea**, (2) **monitorización** y (3) **evaluación**. De esta manera, este estudio contibuye en el debate actual acerca de los procesos cognitivos implicados en IPS que tienen incidencia en la solución de problemas de información con el uso de Internet para aprender contenidos curriculares en las aulas de secundaria.

9.2. Implicaciones educativas

Teniendo en cuenta la contribución de los cuatro estudios llevados a cabo para responder a los objetivos principales de esta tesis, vamos a intentar extraer implicaciones educativas que puedan ser útiles para el diseño de un proceso de instrucción integrado y dirigido al desarrollo de los procesos cognitivos IPS a ser llevado a cabo en el seno de la escuela. Abordaremos diversos aspectos cruciales para el diseño instruccional IPS desde la perspectiva dada por nuestros resultados: (a) instrucción integrada y estructurada, (b) instrucción apoyada desde los diferentes agentes educativos, y (c) coordinación entre los agentes que dan apoyo a dicha instrucción.

(a) El primer punto a considerar es la importancia de la instrucción **integrada**, para ser de este modo coherente con la epistemología contenida en el entorno de aprendizaje (Hannafin, Land & Oliver, 1999) y para que los procesos cognitivos IPS pueden adquirirse dentro de un contexto relevante y significativo, como el currículo académico, no por medio de tareas aislados o desconectadas (Kuiper et al., 2008). Además, es importante destacar que cada proceso cognitivo (cada *skill*, *sub-skill* y actividad de regulación) y el rendimiento de la tarea, están estrechamente relacionadas, según las conclusiones de los estudios 2, 3 y 4. Por lo tanto, es difícil trabajar un proceso específico o habilidad aisladamente de los demás. Por el contrario, puede obtenerse una sinergia muy interesante y positiva en la instrucción que integra cada *skill*, *sub-skill* y actividad de regulación en un proceso IPS conjunto.

Relacionada con este supuesto, una **estructura** definida en la instrucción IPS que guíe a los estudiantes a través de todo el proceso de la resolución del problema podría ayudarles a internalizar todos los pasos –*skills*, *sub-skills* y regulación– necesarios para resolver adecuadamente el problema, proporcionando una base adecuada para la interacción entre el estudiante e Internet (Segers & Verhoeven, 2009).

(b) Teniendo en cuenta el contexto escolar en el apoyo y desarrollo de los procesos cognitivos IPS, varios agentes parecen influir en la eficacia del andamiaje (Kim et al, 2011), que se resumirían en andamiaje tecnológico y andamiaje humano. El **andamiaje tecnológico** se refiere al conjunto de las muchas herramientas que han sido desarrolladas para apoyar el aprendizaje y la enseñanza en las aulas enriquecidas con la tecnología (e. g., Demetriadis et al., 2008; Lindh & Holgersson, 2007; Sánchez, Encinas, Fernandez & Sánchez, 2002). Constituyendo una implicación esbozada por nuestros análisis cuantitativos y cualitativos, los andamios tecnológicos podrían proporcionarse dentro del conjunto de la tarea IPS y podrían parecer en la pantalla en determinados momentos durante el proceso de aprendizaje para apoyar cada actividad *skill*, *sub-skill* y actividad de regulación necesaria para llevar a cabo con éxito una tarea IPS. Estos andamios podrían tomar forma de preguntas, hojas de trabajo, pautas, mensajes emergentes y plantillas. Otra consideración importante es que los andamios deberían perder intensidad gradualmente mientras el progreso del proceso instruccional se va desarrollando, a fin de ayudar a los alumnos y alumnas a internalizar sus IPS *skills* y actividades de regulación, pues de lo contrario el andamiaje no sería suficientemente eficaz (Oliver & Hannafin, 2001).

Los **andamios humanos** son otro conjunto de agentes importante para apoyar el desarrollo de IPS *skills* y actividades de regulación en la resolución de problemas de información durante el aprendizaje de contenidos curriculares. Los andamios humanos son los profesores y profesoras, los compañeros y compañeros, así como otros educadores y educadoras (tales como: padres y madres, familiares, iguales, etc.); sin embargo, en esta tesis nos centramos en el profesorado y los pares de clase, por su presencia en la escuela, que es donde IPS instrucción normalmente se lleva a cabo (o debería llevarse a cabo).

El **profesorado** ha sido sometido a critica por parte de los investigadores por ignorar factores importantes que influyen en el uso de la tecnología en las escuelas (Zhao & Frank, 2003) y ha sido al mismo tiempo considerado como una pieza clave en la instrucción IPS por su actitud y experiencia con las tecnologías, que son cruciales para la utilización de las mismas dentro de un contexto de aula (Becker, 1998; Zhao & Frank, 2003).

Por ejemplo, en el estudio de Land y Zembal-Saul (2003), se diseñó un portafolio para dar apoyo a la reflexión durante un proceso de aprendizaje basado en proyectos (PjBL); sin embargo, los andamios no se utilizaron constructivamente cuando el profesorado fallaba en darse cuenta de que el alumnado no generaba explicaciones adecuadas durante el proceso.

Los profesores y las profesoras que se dedican a ayudar los estudiantes en sus habilidades IPS deberían ser conscientes de las *skills* claves a ser desarrolladas por los alumnos y alumnas: definición del problema, búsqueda de información –especialmente, las *sub-skills* 'especificación de los términos de búsqueda apropiados' y 'selección de resultados adecuados' –, así como de las actividades de regulación que mejoran la resolución de la tarea IPS: orientación en la tarea, monitorización y evaluación. Esto implica que el profesorado debe tener el conocimiento y la experiencia necesarios para resolver problemas basados en información digital, y sería deseable que supiera cómo ayudar a los estudiantes a superar sus dificultades en las tareas IPS, como se ha visto indicado por los investigadores Bryan y Atwater (2002), entre otros.

Sin embargo, algunos profesores y profesoras tienden a usar el andamiaje tecnológico como suplemento a ciertos enfoques de enseñanza en lugar de contextualizar e integrar el conjunto de andamios en la facilitación del proceso IPS de los estudiantes (Cuban, 2001). El andamiaje que considera el profesorado y el andamiaje que considera la tecnología deberían estar bien orquestados y trabajar en la misma línea, complementándose el uno al otro, como se explica más adelante.

Otro importante **andamio humano** presente en las aulas y "aprovechable" durante el proceso instruccional consiste en los propios **estudiantes**. Aunque la investigación ha arrojado resultados inconsistentes sobre las interacciones entre pares en las clases de ciencias (Kim & Hanaffin, 2011), el trabajo entre iguales ha sido considerado por los investigadores una variable instruccional clave que ha contribuido a la mejora de las *sub-skills* involucradas en la 'definición del problema': 'formular preguntas' y 'activar los conocimientos previos' (Walraven et al., 2008). Además, la interacción entre pares permite a los usuarios negociar la idoneidad de los procesos de búsqueda y ofrece la oportunidad a los participantes de observar crítica y mútuamente sus acciones, lo cual puede facilitar la detección precoz y la corrección de posibles errores (Lazonder, 2005; Okada & Simon, 1997). La toma de decisiones conjuntas sobre qué términos de búsqueda escribir en un motor de búsqueda o qué resultado debe ser seleccionado de una SERP podría ser una gran ayuda para fomentar reflexiones específicas y razones individuales que podrían aumentar la capacidad crítica de los estudiantes de secundaria. Además, esta presencia de aprendizaje reflexivo podría permitir el desarrollo de las actividades de regulación, como la orientación, la monitorización y la evaluación. Según Schwartz (1995), los estudiantes que trabajen en pares son generalmente más capaces de aplicar estrategias reguladoras de solución de problemas que los que trabajan individualmente.

No obstante, se han identificado determinados problemas cuando los estudiantes trabajan con sus iguales (Ge & Land, 2003; Barron, 2000). Hannafin et al. (2003) encontraron que los factores más citados que influyen en la calidad de las interacciones entre pares son las siguientes: la 'carga cognitiva' y la 'limitada experiencia previa'. Por lo tanto, el diseño instruccional debería tener en cuenta estos factores si tiene previsto el andamiaje que tiene en cuenta los pares.

(c) Este supuesto nos lleva a considerar el tercer punto de esta sección de discusión general: la **orquestación** necesaria entre los varios tipos de andamiaje (Kim & Hanaffin, 2011). Orquestación no sólo significa que cada agente debe ir en la misma línea que los otros –por ejemplo, cuando el andamiaje tecnológico integrado pretende apoyar el pensamiento crítico de los estudiantes sobre la selección de los resultados de una SERP, el profesorado también debe promover este tipo de pensamiento. Orquestación también significa que los retos que implica uno de los agentes deberían ser compensados por los otros agentes –por ejemlo, si las interacciones entre pares aumentan carga cognitiva de las alumnos y alumnas cuando trabajan con sus iguales, el andamiaje tecnológico tendría que proporcionar ayudas específicas para reducir la carga de memoria de trabajo (Sweller, van Merriënboer, & Paas, 1998).

Otro ejemplo de cómo los agentes pueden compensar retos de otros agentes es el siguiente. Los profesores y profesoras desempeñan varias funciones en las clases basadas en la investigación, como: situar la instrucción en problemas auténticos, tratar con datos, colaborar con estudiantes y profesores, conectar a los estudiantes con la comunidad, modelar el comportamiento científico y fomentar la propiedad del estudiante (Crawford, 2000); sin embargo, el profesorado tiene además múltiples roles adicionales en las aulas enriquecidas con tecnología, tales como: diseñadores, solucionadores de problemas, analistas de contexto, entrenadores y evaluadores (Kim, Hannafin, Adams & Bryan, 2004). En este sentido, los andamios tecnológicos pueden adoptar un papel crucial asumiendo –hasta cierto punto– algunos roles propios de los profesores. Por ejemplo, podría estructurarse una tarea basada en la Web, como se ha descrito anteriormente, para guiar el proceso IPS de manera que el profesor o profesora pueda dedicarse a otros roles precisos que la tecnología no es capaz de asumir.

Diversos tipos de andamiaje interactúan en contextos de aula cotidianos y todos ellos deben estar apropiadamente orquestrados para que se pueda obtener un provecho óptimo de ellos, y como consecuencia, los estudiantes puedan desarrollar los procesos cognitivos IPS clave (*skills*, *sub-skills* y actividades de regulación) en sus aulas, a fin de que puedan mejorar sus competencias digitales que les permitan un adecuado uso de la Web.

9.3. Conclusiones principales

Los principales aspectos que podemos extraer de las conclusiones obtenidas en cada estudio y de la discusión general, se resumen en los siguientes puntos:

- **Existen diferentes técnicas que pueden aportar una valiosa contribución a la comprensión de los procesos cognitivos IPS**. Todas ellas tienen sus limitaciones y potencialidades, y cada una puede complementar las demás. La elección de una u otra técnica para evaluar los procesos IPS **dependerá de los objetivos y el diseño de la investigación** concreta.

- El simple acceso a Internet no garantiza a los alumnos el proceso de resolver satisfactoriamente un problema basado en información digital. El proceso de ressolución de problemas mediante el uso de la información presente en Internet implica complejos procesos cognitivos que no se adquieren de manera espontánea. Por lo tanto, deben aprenderse mediante una **necesaria** alfabetización –la **alfabetización digital**.
- Ya que, por un lado, estamos inmersos en la Sociedad de la Información en la cual Internet es el escenario principal y, por otro lado, la Escuela tiene la misión de capacitar a los estudiantes para que lleguen a ser ciudadanos activos y críticos, resulta **necesaria una adecuada instrucción IPS en la escuela** para ayudar a los alumnos y alumnas a desarrollar sus competencias digitales que les permitan un adecuado uso de la WWW.
- La instrucción IPS puede diseñarse de varias maneras. El proceso instruccional llevado a cabo por el grupo de investigación COnTIC, compuesto por un conjunto de actividades basada en la Web y que ha seguido los tres principios de instrucción descritos anteriormente (integración, estructuración y apoyo), ha sido **eficaz en estudiantes de aulas de Educación Secundaria** para la mejora de los procesos IPS más importantes.
- El andamiaje que apoya un proceso de instrucción IPS debería diseñarse cuidadosamente, de manera que el conjunto de andamiaje humano y tecnológico fuera apropiadamente orquestado, para obtener así el máximo provecho de sus potencialidades.

9.4. Contribuciones, limitaciones y líneas de investigación abiertas

Desde nuestro punto de vista, la tesis de investigación presentada en este informe –con en el propósito de describir los principales desafíos que enfrentan los estudiantes en los procesos IPS, de estudiar el efecto de una instrucción IPS integrada y de extraer conclusiones e implicaciones educativas para la práctica escolar–, constituye una importante contribución en el estudio del campo de la resolución de problemas basados en Información digital, en la medida en que aporta pistas psicopedagógicas y metodológicas valiosas para el estudio de los procesos IPS como parte integrante del aprendizaje y de la enseñanza en el ámbito escolar.

En primer lugar, el conjunto de **análisis de las tres técnicas en el primer estudio de nuestra tesis pueden ser una contribución relevante** para los investigadores de la educación, para los que se dedican a diseñar contextos educativos y para los educadores que se encuentran en el ámbito de la práctica. Por un lado, el hecho de ser conscientes de las diferentes características de cada técnica y del distinto tipo de información que puede proporcionar cada una, son factores críticos para decidir qué técnica de evaluación debería que ser usada en un estudio de investigación y cómo cada una de ellas podrían complementarse entre sí. De hecho, puede ser interesante combinar los datos obtenidos por las distintas técnicas y triangularlos para obtener perfiles individuales de los sujetos más ricos y completos, y poder así esbozar implicaciones educativas y conclusiones más robustas para el diseño instruccional.

Por otro lado, el conjunto de potencialidades de cada técnica puede ser tenida en cuenta para facilitar a los educadores la observación en detalle de los procesos cognitivos IPS de sus estudiantes, a fin de que puedan proporcionarles las ayudas individuales y adecuadas para que puedan superar las dificultades detectadas. Pudiera ser que los educadores que se encuentran en la práctica no tuvieran acceso a los equipos *eye-tracking* para observar los movimientos oculares de sus alumnos y alumnas; sin embargo, sí podrían utilizar técnica de *logfiles* para observar el proceso IPS de sus estudiantes de una manera que no obstaculizara su proceso ni su contexto natural y detectar de esta manera puntos a ser mejorados, especialmente los relacionados con la especificación de los "términos de búsqueda" o la "selección de los resultados de una SERP" durante una tarea IPS llevada a cabo en el aula. Además, podría también utilizarse la técnica "*cued-retrospective reports* basados en sus propios *logfiles*" cuando el equipamiento *eye-tracking* no fuera accesible. Todo ello podría facilitar una mayor comprensión de los procesos cognitivos implicados en IPS.

Aparte de la contribución para los investigadores y educadores, las conclusiones de este primer estudio acerca de las distintas potencialidades y características de cada técnica pueden ser generalizadas al análisis de los procesos cognitivos involucrados en otro tipo de tareas o entornos, como la interacción entre iguales, el aprendizaje colaborativo, el aprendizaje de la autorregulación, el *game-based learning* u otros.

Otra importante contribución de esta tesis es el conjunto de **conclusiones sobre la evaluación de la instrucción IPS integrada, estructurada y apoyada**. Nuestras conclusiones muestran el potencial de dicha instrucción en el desarrollo de procesos IPS de los estudiantes. En nuestra opinión, este tipo de intervención educativa podría contribuir en la mejora de las competencias digitales de los alumnos y alumnas que puedan permitirles una mejor utilización de la información de la Web y participar plenamente en nuestro mundo global del conocimiento. Las características de este tipo de instrucción IPS, o algunas de ellas, pueden aplicarse también a otros niveles educativos. Pueden constituir un ejemplo adecuado y aprovechable para educadores, diseñadores, investigadores, etc.

Por último, los **patrones y secuencias IPS** elaborados en esta tesis, en particular en el estudio 4, pueden constituir una **contribución valiosa para ilustrar el proceso** seguido por los estudiantes durante la resolución de un problema mediante información digital, así como para compararse dichos procesos entre ellos a fin de detectar dificultades a superar y también modelos expertos a imitar.

Además de estas contribuciones, es importante tener en cuenta las **limitaciones** de nuestro estudio. Por un lado, la técnica utilizada para recoger los datos ha sido la técnica de *logfiles*, la cual puede implicar ciertos hándicaps por las razones presentadas en el estudio 1 (capítulo 5). La principal limitación encontrada es el riesgo de sobreinterpretar las acciones realizadas por los participantes. Debido a que esta técnica sólo capta las acciones ejecutadas en la pantalla del ordenador y no otras informaciones como los gestos de los individuos, podrían malinterpretarse fácilmente algunas de ellas. La elección de esta técnica fue debida a la validez ecológica y el nulo entrometimiento de la técnica en el proceso natural de resolución de problemas en el aula, aspecto difícil de conseguir con las otras técnicas analizadas en el estudio 4.

Por otro lado, otra limitación de esta disertacion pudiera ser que el foco ha sido dado primordialmente a los procesos IPS de los estudiantes. No obstante, otros agentes tecnológicos y humanos presentes en el aula (por ejemplo, el profesorado o los iguales) y su proceso de orquestación conjunta, no han sido tenidos en cuenta directamente en este estudio. La observación y el análisis de dichas variables podrían haber aportado información valiosa para una evaluación más finamente matizada sobre su repercusión en el desarrollo de los procesos IPS en el aula.

Estas limitaciones nos llevan a esbozar **nuevas líneas de investigación abierta**s como continuación de esta investigación. Una de estas líneas se refiere a las técnicas a ser utilizadas en el proceso de recogida de datos y las ventajas de la complementación entre unas y otras. Un **análisis más profundo de los procesos cognitivo**s mediante *logfiles* se vería facilitado por el **uso complementario de las otras técnicas**, como *eye-movements* o *cued-retrospective reports*, como se explica en el estudio 1 (capítulo 5) y como se ha venido mencionando a lo largo de este capítulo.

Además, consideramos el profesorado como agente humano y elemento clave en el proceso de instrucción IPS. Tal como hemos señalado anteriormente, el análisis del **rol del profesor** podría contribuir en una comprensión más intensa de la dinámica de las aulas enriquecidas con tecnología y en el diseño de nuevas estrategias de enseñanza y aprendizaje que involucren procesos de resolución de problemas con información digital (Crawford, 2000; Claves de & Bryan, 2001; Nespor, 1987). Asimismo, la orquestación entre los varios agentes (tecnológicos, iguales y profosorado), tal como se ha comentado más arriba, podría constituir un tema muy importante para la mejora del diseño de ambientes de aprendizaje estimulantes y provechosos en las aulas.

En este sentido, **toda la comunidad educativa** podría también ser digna de ser analizada. Los procesos IPS y la interacción con las tecnologías de la información y la comunicación también se llevan a cabo (incluso con mayor extensidad) más allá de las paredes de la escuela. Los padres y madres, familiares, amigos y amigas (también los virtuales) y medios de comunicación son posibles factores influyentes en la utilización y en la actitud hacia el uso de Internet como una herramienta de información y comunicación (Cuban, 2004).

Otra interesante línea abierta para la investigación se refiere a las **potencialidades** que las TIC poseen y a las que se les puede sacar un **provechoso partido en la escuela** para aprender contenidos curriculares. En esta tesis de investigación nos hemos centrado en el análisis de los procesos IPS desempeñados por los estudiantes y hemos considerado la necesidad de la alfabetización digital como una de las razones de mayor peso para incluir un proceso de instrucción IPS en la escuela. No obstante, desde nuestro punto de vista, otra enorme razón para integrar las tecnologías de información y comunicación en las instituciones educativas se relaciona con las inmensas potencialidades que aportan a los procesos de enseñanza-aprendizaje (Coll & Monereo, 2010).

La combinación entre **aprendizaje colaborativo** y **Web 2.0** supone otra línea abierta para la investigación. Vivimos en un mundo globalizado e interconectado en el que la WWW es uno de los escenarios principales de acción. Este nuevo mundo está cambiando constantemente así como la propia Web. Ésta se ha transformado de un conjunto de páginas HTML estáticas en el cual los usuarios acceden y manejan la información contenida en ellas (el enfoque principal de esta tesis) hacia un conjunto de servicios interactivos en los cuales los usuarios pueden crear y publicar información ellos mismos. La Web es ahora un lugar interactivo y participativo donde podemos crear información de manera colaborativa y compartir conocimiento. Por lo tanto, la evolución de la Web hacia la Web 2.0 refleja cambios profundos en la organización social, económica y cultural. Estos cambios demandan nuevas habilidades cognitivas en los jóvenes ciudadanos y el desarrollo de nuevas competencias acerca de cómo utilizar y sacar provecho de todas estas potencialidades, especialmente para colaborar y aprender conjuntamente.

Por último, cabe recordar que los PCs o portátiles ya no son el único camino para acceder a Internet, ya que se puede entrar a la Web desde diferentes dispositivos. El "aprendizaje desde el móvil" (o "m-learning"), por ejemplo, está siendo cada vez más ampliamente estudiado como una forma de aprendizaje como apoyo en las aulas o fuera de ellas. El m-learning ha sido también definido como el aprendizaje que ocurre cuando el usuario no está en una ubicación fija o predeterminada, o como el aprendizaje que se da cuando el usuario saca partido de las oportunidades de aprendizaje ofrecidas por las tecnologías móviles (O'Malley, Vavoula, Glew, Taylor, Sharples & Lefrere, 2003, Tremblay, 2010). El m-learning se centra en la movilidad del estudiante, en la interacción con tecnologías portátiles y en un tipo de aprendizaje que refleja que la sociedad y sus instituciones pueden acomodarse y dar cabida a una población cada vez más relacionada con el móvil. M-learning es conveniente en cuanto que es accesible desde prácticamente cualquier lugar, lo que revela un aumento de las oportunidades ubicuas para el aprendizaje mediante Internet en nuestra sociedad.

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