Argelagós, E., Garcia, C., Privado, J. & Wopereis, I. (2022). "Fostering information problem solving skills through online task-centred instruction in higher education". *Computers & Education*, vol. 180, art. num. 104433

The final published version of the article is available online at:
https://doi.org/10.1016/j.compedu.2022.104433

Fostering information problem solving skills

through online task-centred instruction in higher education

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Abstract

The competence to perform an academic literature review task in a digital context is of paramount importance for higher education students. However, both undergraduate and graduate students have difficulty finding, analysing, and processing such information for their academic tasks. Recent studies propose a task-centred approach to teach relevant knowledge and skills to perform review tasks. This paper presents a quasi-experimental study on the effects of an online task-centred course on the IPS skills development and self-efficacy perception of 80 graduate students in educational sciences. The Information Problem Solving (IPS) and Four-Component Instructional Design (4C/ID) models have been applied for course design and development. The results indicate that, after the course, students in the experimental group outperformed the control group on planning and search activities. These students also seemed to do better at defining research questions and processing the information found, though these results were not statistically significant. Finally, no differences were found related to the ability to present information. In addition, self-efficacy related to the IPS skills needed to perform an academic literature review task developed positively in the experimental group. Implications for instruction on these IPS skills in higher education are discussed.

Keywords: digital information, task-centred instruction, information problem solving, higher education, online education, literature review

1. Introduction

In contemporary education, the ability to manage digital information is essential to learning. Students at all levels are exposed to increasing amounts of digital data, which requires skills for handling them effectively and efficiently (European Commission, 2018). In higher education, we expect students to be able to manage the exponential growth of the information available online (Deja et al., 2021). However, contemporary research has shown that students at all educational levels often lack the ability to use digital information in an appropriate way (Walraven et al., 2008; Zhou & Lam, 2019). They do not become expert information problem solvers by intensive internet use only, but need explicit instruction to reach that status (Rosman et al., 2016c; Salmerón et al., 2017; Weber et al.,2019).

Wopereis et al. (2015, 2016) showed that undergraduate students in educational sciences benefited from task-centred instruction (see Francom, 2017; Van Merriënboer, 2007) on information problem solving (IPS) skills relevant to performing literature reviews for a master's thesis. Such instruction includes a variety of learning tasks that are based on authentic, professional tasks (in this case 'conducting literature reviews'). The current study examines the effects of a similar type of instruction on review ability using different measurements in a different context (students from various Spanish-speaking countries). As such, it aims to expand our knowledge on effective, efficient, and appealing IPS instruction (cf. Brand-Gruwel & Wopereis, 2006; Dolničar et al., 2016; Frerejean, Van Merriënboer et al., 2019; Garca & Badia, 2017; Pifarré & Argelagós, 2020). In our study, we present the improvement of IPS skills to perform an academic literature review task by means of a formal online course. We also report on the enhancement of perceived self-efficacy related to those skills, because this can serve as a complementary and valuable measure to reveal the development of complex IPS skills (Rosman at al., 2015). The course can be characterized as task-centred instruction and was constructed using design guidelines that are central to the Four-Component Instructional Design (4C/ID) model (Van Merriënboer & Kirschner, 2018).

1.1. Information problem solving

The process of finding and managing information in online academic databases in order to construct knowledge requires the competence to search for the appropriate information in reliable online sources and integrate this information in a significant way with existing knowledge. This ability or complex cognitive skill is often referred to as information literacy (IL) or information problem solving (IPS).

The Association of College and Research Libraries defines IL as a set of skills to search for, assess, and use information that is necessary to solve information problems (ACRL, 2016). In addition, this association presents a framework that includes a variety of competency standards for higher education. Thus, an information literate individual should be able to: (1) determine information needed; (2) access the needed information in an effective and efficient way; (3) assess information and its sources critically and incorporate selected information into one's knowledge and values; (4) use information effectively to accomplish a specific purpose; (5) understand the economic, legal, and social issues surrounding the use of information, and access and use information in an ethical and legal manner.

This collection of skills reflects the IPS model (Brand-Gruwel et al., 2005; Brand-Gruwel et al., 2009; Dinet et al., 2012; Frerejean, Velthorst et al., 2019; Raes et al., 2012). This model shows that (a) the constituent skills necessary to execute steps in the IPS process have strong ties (Garcia & Badia, 2017) and (b) regulation skills such as planning, monitoring, and evaluation are essential to IPS (Winne, 2019). The IPS model depicts five constituent skills that are all related to steps in the IPS process: (1) defining the problem, (2) searching for information, (3) scanning information, (4) processing information, and (5) organizing and presenting information found. In addition, each constituent skill is subdivided into several sub-skills; for instance, defining the problem involves the sub-skills of reading and understanding the assignment, activating prior knowledge, determining the needed information, and formulating driving questions that could lead to a better search.

In higher education, the overall IPS process is crucial to learning tasks that include a systematic review of scientific literature (Birkett & Hughes, 2020; Wopereis et al., 2015). Research shows that students do not merely acquire this skill by browsing the web, but that explicit instruction is necessary (Badia & Becerril, 2015; Wopereis et al., 2008). Studies indicate that students who are now entering the higher education system need ample instructional support to learn IPS in a scientific context (Brand-Gruwel et al., 2005; Donnelly et al., 2018; Frerejean et al., 2016, 2018; Henkel et al., 2018; Kirschner & van Merriënboer, 2013; Hinchliffe et al., 2018; Lanning & Malleck, 2017; Mahmood, 2016; Smith et al., 2013).

Figure 1. Information problem solving skills to review scientific literature (inspired by Brand-Gruwel et al., 2005; adapted from Garcia et al., 2020).

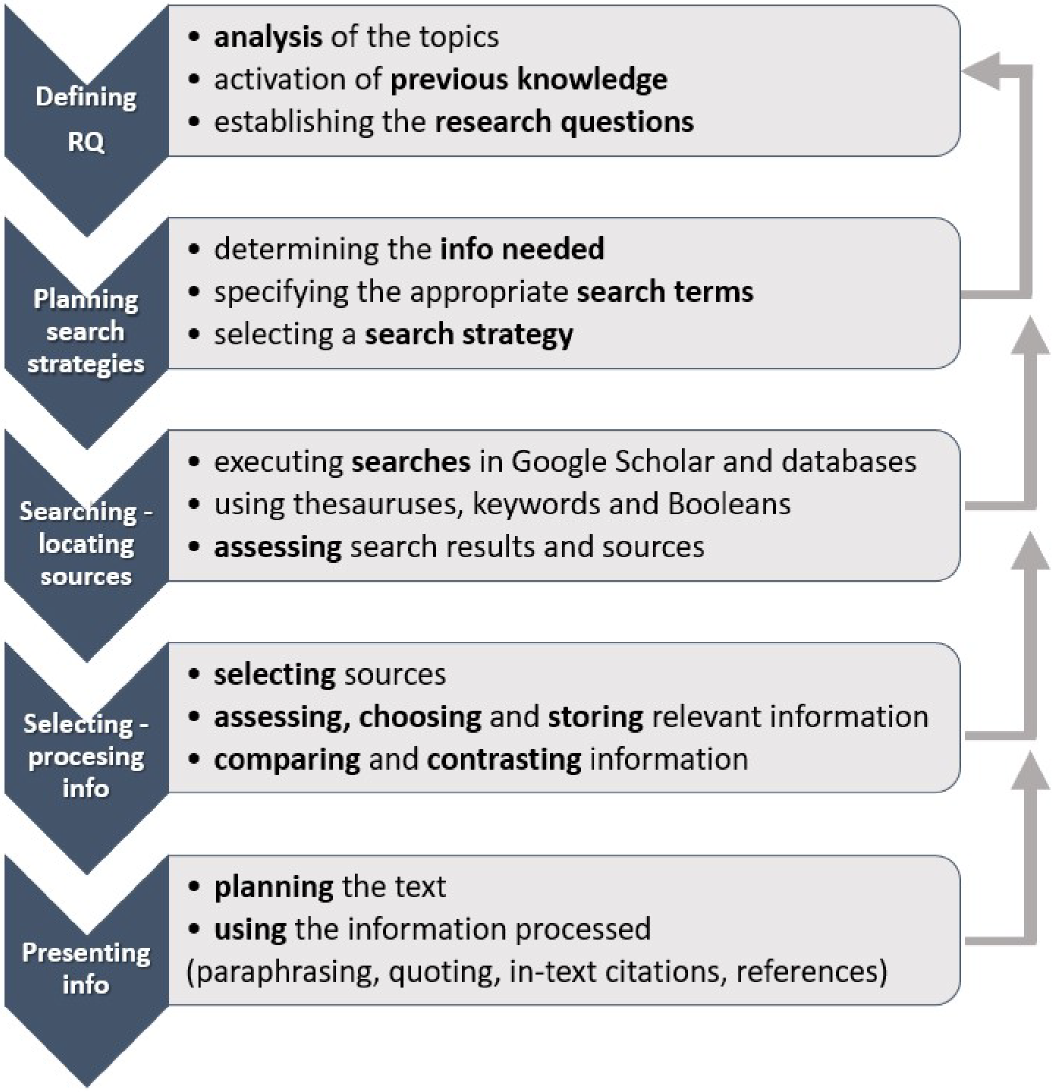


Figure 1 shows the IPS skill decomposition that serves as a basis for this study. The constituent skills are equivalent to the IPS model of Brand-Gruwel et al. (2005), but they are grouped in a slightly different manner, based on the validation study of the PIKE-E test (Garcia et al., 2020), as explained in section 2.2. The first constituent skill is *defining research questions*, which consists of the knowledge, skills, and attitudes needed to analyse the topic of interest, activate prior knowledge on that topic, and formulate research questions related to the selected topic. The second constituent skill relates to *planning search strategies*, which is needed to prepare the search and includes actions such as determining the information needed, specifying the search terms, and selecting a search strategy. This includes using a thesaurus to find adequate keywords, using Boolean operators to specify a query, and deciding which scientific databases to use (e.g., ERIC, PsycINFO, SSCI, or Google Scholar). The third constituent skill is devoted to *searching and locating sources* necessary to answer the research questions that were formulated. This involves the execution of search queries planned above and generally checking the reliability and content of sources before deciding to access them.

The fourth constituent skill relates to *selecting sources and processing information*. This includes (a) selecting adequate and useful sources to answer the research questions, and (b) assessing, storing, and organizing the relevant information of the sources, by means of summaries that include references, key points, and arguments for why the sources are considered relevant. This constituent skill also includes the analysis and extraction of relevant information from the selected texts and the integration of the information found with prior knowledge. Finally, the fifth constituent skill encompasses *presenting information*, which includes the planning and execution of scientific writing processes.

1.2 Information problem solving instruction in higher education

In (applied) science, IPS commonly refers to searching and synthesizing the results of peer-reviewed research on a specific topic that is documented in scientific literature. It constitutes the literature review task, which is usually the starting point of research, development, and innovation projects. In large-scale projects, it can be a recurrent task. Literature review tasks vary in complexity according to the nature of the subject (new topic versus well-researched topic), a researcher's prior knowledge of a subject (high versus low topical knowledge), the methods used to collect, synthesize, and present the results (standard versus sophisticated ones), and constraints related to task execution (high versus low financial and human resources). Based on complexity, one can broadly divide literature research tasks into traditional, systematic, and meta-analytical instances (Jesson et al., 2011). Our study focuses on instructional design for learning a set of tasks that belong to the first two categories.

Many contemporary instructional theories and models that guide educationalists through the process of designing instruction for complex cognitive skills, like conducting a literature review, are holistic by nature (Francom, 2017; Merrill, 2002; Reigeluth & An, 2021; Van Merriënboer, 2007). They are often referred to as task-centred and aim at the development of instruction that supports the learning of an integrated knowledge base that prospective professionals need in order to perform a wide variety of future authentic tasks. Such instruction increases the potential for transfer of learning.

1.2.1 Task-centred instruction

Francom (2017) introduced the concept of task-centred instruction (TCI) to emphasize the key principle of design which says that learning is centred around whole tasks that are based on real-world (professional) tasks. This holistic view of instructional design helps to prevent compartmentalization and fragmentation in educational programmes as it aims at designing instruction that facilitates the integration of knowledge, skills, and attitudes in an interconnected flexible knowledge base (Van Merriënboer & Kirschner, 2018). Other design principles that make up TCI are (a) activation of prior knowledge, (b) demonstration/modelling, (c) application, and (d) integration/exploration (Francom, 2017). Merrill (2002) labels these five design principles the 'first principles of instruction' and indicates that Van Merriënboer's Four-Component Instructional Design

(4C/ID; Van Merriënboer & Kirschner, 2018) model best adheres to them. It is this instructional design model that was chosen as the premise for designing the intervention in the current study.

1.2.2 The 4C/ID model

As a paragon of task-centred instructional design, the 4C/ID model emphasises the importance of taking whole task instruction as the point of departure for the design process. This is reflected in the ten-step design approach proposed by Van Merriënboer and Kirschner (2018) that accompanies 4C/ID, where designing comprehensive learning tasks based on authentic (professional) tasks is the first design step. For an extensive overview of the design steps needed to design the main components of task-centred instruction, we refer to Van Merriënboer and Kirschner (2018). In this section, we will restrict ourselves to an explanation of the four components that constitute good IPS instruction, in order to provide insight into the content of the course (see Sections 2.3.3 and 2.3.4).

The 4C/ID model highlights four components that are necessary to create an educational programme for complex skill learning. These components are: (1) learning tasks, (2) supportive information, (3) procedural information, and (4) part-task practice (Frerejean et al., 2021; Frerejean, Van Merriënboer et al., 2019; Van Merriënboer, 2007; Van Merriënboer & Kirschner, 2018).

Learning tasks are the backbone of such a programme and refer to cases, projects, professional tasks, or assignments. Learning tasks are rooted in authentic tasks and are presented to learners in simulated (school sites, online courses, multimedia programmes) or real-life environments (workplace). Performing a varied set of learning tasks results in inductive learning. Ideally, this set is offered sequentially from simple to complex with incrementally decreasing support and guidance (scaffolding). Learning tasks require both non-routine and routine skills.

Supportive information helps students to perform the non-routine aspects of learning tasks, which require problem solving, reasoning, and/or decision making. This kind of information is often called ‘the theory’ and is presented to students as paper-based and/or digital (online, multimedia) textbooks, handbooks, and resources such as white papers, journal articles, and encyclopaedic reference works. Methods for presenting supportive information aim at the construction of knowledge in a process that is called elaboration.

Procedural information, the third component, is needed to learn the routines that are part of task performance. Because it is offered to students at the moment it is needed during task performance, it is also called ‘just-in-time information’. Methods used to learn procedural information enhance a learning process that is called rule formation.

Part-task practice is the final component of the 4C/ID model. This component also focuses on learning routines, but those that require a high degree of automatization. Instructional methods include excessive repetition that results in strengthening cognitive rules in long-term memory, in order to form routines that are similar across different tasks. These ‘if–then’ structures guarantee that similar responses are appropriately executed in similar contexts. This contributes to the automaticity of routines.

Van Merriënboer and Kirschner (2018) outlined a ten-step procedure for designing instruction according to the aforementioned four components. Both the 4C/ID model and the ten steps to complex learning have been applied to design instruction for obtaining IPS proficiency (Costa et al., 2021; Frerejean, Van Merriënboer et al., 2019).

1.3. Self-efficacy

Self-assessments are frequently used when measuring information literacy and IPS skills (Walsh, 2009). Although self-assessment by itself does not warrant that the perception of achievement is equal to actual achievement (see Young et al., 2019), measuring self-efficacy could be highly valuable as a complement in the development of complex IPS skills (Rosman et al., 2015). A self-assessment is a promising instrument because:

- the subjective ability to assess self-efficacy is often a motivation for performance (Bandura, 2010; Deja et al., 2021; Ozcal, 2019) and can help students to persist with tasks, in particular when they are experiencing difficulties (Shunk, 1984; Wedderhoff et al., 2018);
- assessment of one's skills and performance can positively influence subsequent performance (Spisak, 2018), as individuals can easily identify their strong and weak points, in a metacognitive way, and therefore better regulate their process (Boud, 1995; Lew et al., 2010);
- self-assessments might be a useful tool for learning and self-reflection (Dochy et al., 1999; Doyle et al., 2019; Spisak, 2018); there are some aspects of information literacy that are more difficult to measure by achievement tests, such as regulation activities -i.e., they imply thoughts, feelings, and reflection about one's own actions, which are well known to the individual (Zimmerman, 2000)-, but that are well suited to examination by means of self-assessment tests (Falchikov, 2005; Oscarson, 1989).

Considering these four reasons, IPS self-assessments also have the potential to be a useful complement to other instructional strategies. Measuring self-efficacy related to IPS or IL with self-assessment instruments can make students aware of their deficiencies, which can be beneficial for the learning and development of IPS skills.

Rosman et al. (2015) recommend that researchers and practitioners include self-assessments when investigating students' information literacy skills, due to the advantages mentioned above. They suggest administering self-assessments *after* ability tests, because of the potential for metacognition and regulation of the self-assessment instruments, and they strongly recommend not to assess those skills with self-reports alone, as an alternative to performance tests. In the study by Spisak (2018), for instance, which compared self-efficacy and performance tests, some secondary students overestimated their information literacy abilities. However, self-assessment was administered *before* the performance test, which could be a factor in diminishing the adequacy of the results of the self-assessment. Other studies used a self-report alone (e.g., Whitelock-Wainwright et al., 2020) and acknowledged the limitations of relying solely on self-report measures and the need to use more objective data.

1.4. Objectives and hypothesis

The present study investigates the effect of task-centred instruction, with whole and authentic tasks, on higher education students' IPS skills development. Specifically, the intervention aimed at improving the students' skills to review scientific literature in order to perform an academic task in a digital context.

Therefore, this study aims to answer the following two questions:

RQ1: Does task-centred instruction improve the IPS skills needed to carry out an academic literature review task in an online higher education environment?

RQ2: What is the effect of task-centred instruction on IPS self-efficacy expectations?

Considering the empirical findings available so far, it can be predicted that the task-centred instruction informed by the IPS and 4C/ID models will be effective in enhancing the complex skills needed to use digital information for academic purposes. More precisely, it is expected that the students receiving this training will obtain significantly better scores on the IPS skills test than the students who do not receive it. Additionally, we hypothesize that these students' self-efficacy expectations on their ability to review scientific literature for academic purposes will be greater than students without training.

2. Method

2.1 Participants

80 graduate students (14 male; 66 female) in educational sciences at the Universidad Internacional de la Rioja (UNIR), an online university, participated in this study. Their mean age was 36.86 years (*SD* = 8.44). Participants lived in Spain (17.5%), Colombia (41.3%), Ecuador (38.8%), or other countries (2.6%). As explained in section 2.3.1, 25 students belonged to the experimental group and 55 to the control one.

2.2 Design and measures

This quasi-experimental study used a non-equivalent control group pre-test post-test design to establish the effects of task-centred IPS instruction. It applied two tests to measure instructional effects

The *Procedural Information Problem Solving Knowledge Evaluation – Education* (PIKE-E) *test* (Garcia et al., 2020) is a Spanish adaptation of the PIKE-P

(Rosman et al., 2016b). The latter was designed to measure psychology students' IPS knowledge; however, it did not analyse the factorial structure of their test and assumed that all the items formed a single factor. Further, PIKE-P did not measure constituent IPS skills such as assessing, processing, and presenting information found. Therefore, it was less suitable for measuring knowledge on performing whole IPS tasks. The PIKE-E test was developed to overcome these limitations and to represent a validated test to assess students' procedural knowledge on the ability to review scientific literature needed to write an academic text in the domain of educational sciences. It consists of 26 performance items that are grouped into five first-order factors, named *Defining research questions*, *Planning search strategies, Searching and locating sources*, *Selecting and processing information*, and *Presenting information*, respectively (see Figure 1). These five first-order factors are grouped into one general second-order factor called IPS (Cronbach's alpha = .801 in the pre measure and .856 in the post measure).

The *Self-Efficacy Scale for Information Searching Behaviour* (SES-IB-16; Behm, 2015; Rosman et al., 2015) is a questionnaire for measuring self-reported information literacy. It consists of 16 items with a five-point Likert-scale format. The SES-IB-16 covers all phases of the IPS process. The items relate to different criteria that define IPS. The internal consistency (Cronbach's alpha) of the test in the pre measure was .913 and in the post measure was .941.

2.3. Procedure

2.3.1. Recruitment and allocation of participants

Students from different educational master's programmes at the Faculty of Education of UNIR received an invitation by email to participate in a two-month online course (60-hour study load) on the development of the IPS skills needed to review scientific literature in a digital context. The students participated voluntarily in this free pilot course, which prepared them for their master's project.

To register for the course, they had to fill in a digital form that recorded their demographic data. In addition, they had to perform two pre-tests: the PIKE-E and the SES-IB-16. Upon completing the forms, students voluntarily accepted the conditions to participate in the research according to the University's ethical standards. Students could leave either the course or the research whenever they wanted.

120 students started the course. 25 students completed all learning tasks; they formed the experimental group. The control group included 55 students who completed the pre-tests but could not attend the first run of the course due to a limitation on the number of participants. They completed the post-tests before they enrolled in the second run of the course. Participants of the control group thus received no training before the pre-tests and post-tests; however, they received it in the second run of the course, which was carried out immediately after the first run. The time spent between the pre- and the post-test (both experimental group and control one) was two months.

2.3.2. Aim of the course

At Spanish universities, a final degree thesis takes the form of an essay or report that each student prepares autonomously under the guidance of a supervisor. This requires a theoretical foundation that must be supported by relevant and reliable bibliographic sources. Therefore, the task-centred online course aimed at developing IPS skills necessary to choose and select reliable and rigorous academic references, and to write a concise scientific text on the findings, in order to provide the theoretical framework for their master's thesis.

2.3.3. Course materials

Following the 4C/ID model (see section 1.2.2), the online course included five learning tasks (see Table 1), the theory related to learning tasks (supportive and procedural information), and feedback on the students' task practice.

Table 1. Overview of learning tasks during the online course

Learning task	Session	Topic
1. Modelling example	1	Gamification and learning
2. Explanation and modelling	1 to 6	Cyberbullying in early childhood education
3. Performance constraints	1 to 6	Metacognitive strategies in primary education
4. Prompts	6 to 7	Cooperative learning
5. Conventional task	7 to 8	Personal choice of each student

2.3.4. Online course

The backbone of the online course consisted of five learning tasks that aimed at fostering the IPS skills needed to perform an academic literature review task in a digital context. Each learning task included the five IPS skills and therefore was considered a 'whole task'. Tasks were based on authentic professional tasks in the domain of educational sciences. Table 1 and Figure 2 summarize the learning tasks.

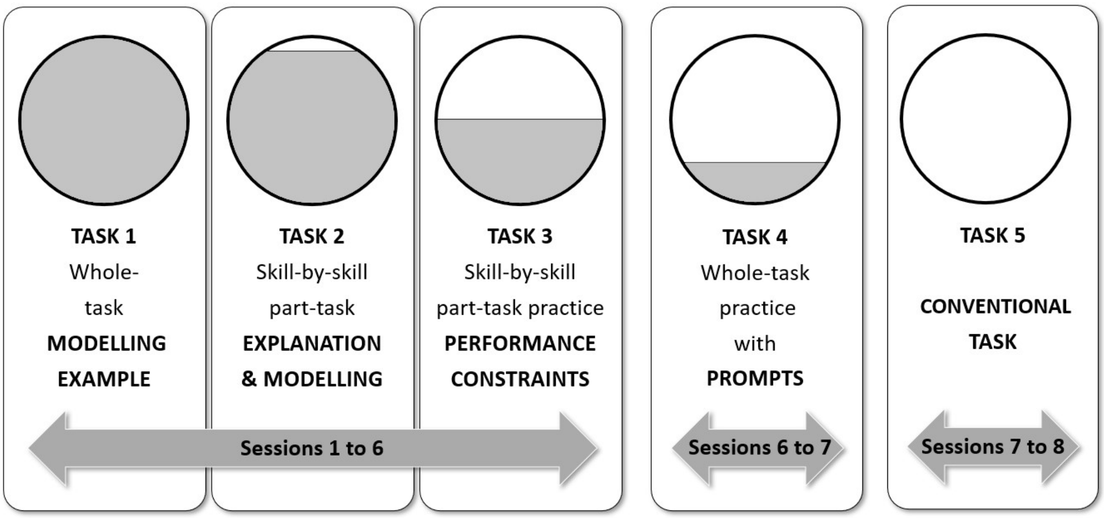
Figure 2. Tasks carried out during the instruction; the grey area in each circle shows the level of support given for each task.

- *TASK 1*. The first learning task was a modelling example that was presented in the first online virtual classroom session[1] delivered through Adobe Connect, and that students had to work on.

[1] Each session had a duration of one hour.

- *TASK 2*. In the same session, the first skill of the second learning task was explained in a distributed way, i.e., in five partial tasks. In five consecutive sessions the constituent IPS skills were taught, and general and individual feedback was given to the students on their practice. In order to avoid the tendency towards fragmented learning derived from a part-task approach in which students do not learn the transitions between skills (Francom, 2017), the instructors placed particular emphasis on the relations that exist among these transitions and the iterative nature of conducting a literature review for developing a theoretical framework for a final master's thesis. In addition, during these sets of sessions, the principle of performance constraints was applied (Van Merriënboer & Kirschner, 2018), whereby students were only allowed to go to the instruction of the next constituent skill if they had mastered the previous one.
- *TASK 3*. After each session in which an IPS skill was instructed, students had to practise that skill in a third task, as homework for the following session. Figure 3 shows the procedure followed during the first six sessions (tasks 1, 2, and 3), in which the classes were combined with the support material (modelling example videos and learning documents) and the obligation to carry out a partial task related to the corresponding IPS skill for the next class, to be discussed and to be the subject of general and individual feedback.

Figure 3. Actions during sessions 1 to 6 (tasks 1 to 3). Teacher ‘instructs’ means ‘explains and models’. Student ‘studies’ means ‘watches the modelling example video and reads the learning materials’; ‘practises’ means ‘carries out the task’.



- TASK 4. The fourth learning task was devoted to solving a whole task with prompts to accomplish the five iterative IPS skills learned in the previous tasks. After the fourth task, the students received individual written feedback from the instructors about the strong and weak points showed during the resolution of the task carried out on their own.
- TASK 5. The fifth learning task consisted of a conventional task without any help. Students were asked to perform the last whole task and, as a result, to write a short text on their final master’s thesis based on the instruction received, and general and individual feedback was given to them. In the last session of the instructional course, students were asked to complete the post-tests.

2.4. Data collection and data analysis

The pre-tests consisted of an online form that included the registration of demographic data, the PIKE-E, and the SES-IB-16. The online post-test included the PIKE-E and the SES-IB-16.

Data analysis consisted of (a) the calculation of the distribution of scores on the PIKE-E and SES-IB-16 tests, (b) the study of the effectiveness of the course by means of a mixed analysis of variance (ANOVA) using group (experimental and control) as an intergroup factor, and the pre-test and post-test results of the PIKE-E and the SES-IB-16 as an intragroup factor. We performed the analyses with SPSS, v.18.

3. Results

In this section, we successively present (a) the descriptive data of the pre-test and post-test measures, (b) the effects of the online IPS course on the IPS process and its constituent skills, and (c) the effects of the same course on students' self-efficacy regarding information literacy.

Descriptive data. Table 2 shows the descriptive statistics of the different measures on the two occasions that they were applied (pre-test and post-test), as well as the asymmetry and kurtosis indices obtained by dividing their corresponding statistics among the typical measurement errors. Values below $| \pm 1.96 |$ indicate a symmetric and mesokurtic distribution of the variables. As can be seen, all the measurements are mesokurtic and there are only small variations of symmetry in three measures, so we can consider that the distribution is normal. In any case, the ANOVA is a very robust test against the failure of the normality assumption (Pardo & San Martín, 2015). The other assumptions of ANOVA, the homoscedasticity and equality of covariances, were analysed in each of the different analyses (see Table 3). Levene's test for equality of variance is maintained in all cases ($p > .050$), as is Box's test for the equivalence of covariance matrices ($p > .050$).

Table 2. Descriptive data of the pre and post measures

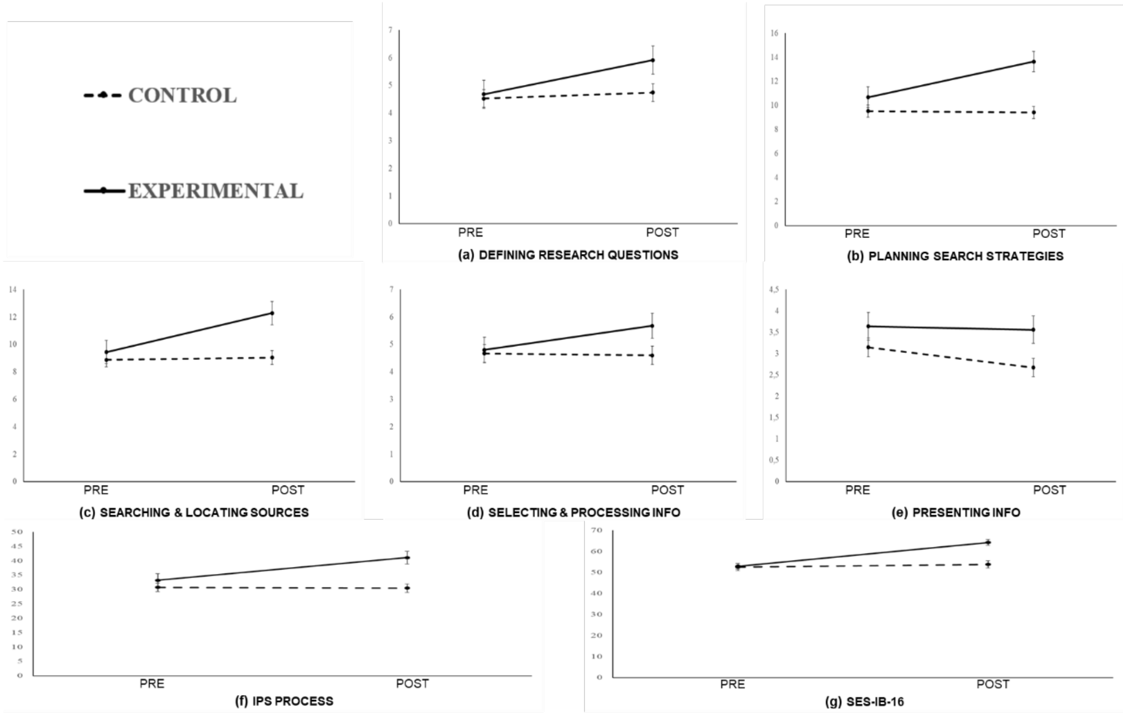
Test	Focus	Mean	SD	Asymmetry Index	Kurtosis Index
Pre	Defining research questions	4.58	2.41	-1.09	-0.79
Pre	Planning search strategies	9.89	3.35	-2.60	0.43
Pre	Searching-locating sources	9.05	3.25	-0.78	-1.00
Pre	Selecting-processing info	4.71	2.33	0.96	-1.12
Pre	Presenting info	3.30	1.55	-2.01	-0.24
Pre	IPS process	31.53	9.93	-2.39	0.19
Pre	SES-IB-16	52.71	9.74	-0.86	-0.73
Post	Defining research questions	5.11	2.79	-0.62	-1.56
Post	Planning search strategies	10.74	5.08	0.31	0.03
Post	Searching-locating sources	10.05	4.01	-1.39	-1.55
Post	Selecting-processing info	4.94	2.56	0.53	-1.69
Post	Presenting info	2.95	1.73	-1.56	-1.59
Post	IPS process	33.79	13.70	-1.59	-0.51
Post	SES-IB-16	57.13	11.18	-0.31	-0.86

Table 3. Results of the mixed ANOVA for each dependent variable

Skill	Group	Mean (SD)		Intra-subject effect		Inter-subject effect	Box's test	Levene's test	
		Pre	Post	Factor	Interaction			Pre	Post
Defining research questions	Control	4.53 (2.37)	4.75 (5.92)	$F_{1,78} = 5.36$, $p = .023$, $\eta^2_{partial} = .064$	$F_{1,78} = 2.63$, $p = .109$, $\eta^2_{partial} = .033$	$F_{1,78} = 1.51$, $p = .223$, $\eta^2_{partial} = .019$	$F_{3,47046} = 0.27$, $p = .850$	$F_{1,78} = 0.39$, $p = .535$	$F_{1,78} = 0.34$, $p = .560$
	Experimental	4.68 (2.53)	5.92 (2.56)						
Planning search strategies	Control	9.53 (3.24)	9.42 (4.43)	$F_{1,78} = 7.83$, $p = .006$, $\eta^2_{partial} = .091$	$F_{1,78} = 9.07$, $p = .004$, $\eta^2_{partial} = .104$	$F_{1,78} = 10.18$, $p = .002$, $\eta^2_{partial} = .115$	$F_{3,47046} = 0.85$, $p = .465$	$F_{1,78} = 0.03$, $p = .859$	$F_{1,78} = 1.16$, $p = .286$
	Experimental	10.68 (3.51)	13.64 (5.31)						
Searching and locating sources	Control	8.87 (3.28)	9.04 (3.82)	$F_{1,78} = 13.08$, $p = .001$, $\eta^2_{partial} = .114$	$F_{1,78} = 10.38$, $p = .002$, $\eta^2_{partial} = .117$	$F_{1,78} = 6.69$, $p = .012$, $\eta^2_{partial} = .079$	$F_{3,47046} = 0.37$, $p = .774$	$F_{1,78} = 0.13$, $p = .721$	$F_{1,78} = 1.39$, $p = .243$
	Experimental	9.44 (3.22)	12.28 (3.54)						
Selecting and processing info	Control	4.67 (2.39)	4.60 (2.59)	$F_{1,78} = 1.55$, $p = .217$, $\eta^2_{partial} = .019$	$F_{1,78} = 2.78$, $p = .146$, $\eta^2_{partial} = .027$	$F_{1,78} = 1.52$, $p = .222$, $\eta^2_{partial} = .019$	$F_{3,47046} = 0.14$, $p = .934$	$F_{1,78} = 0.77$, $p = .384$	$F_{1,78} = 0.94$, $p = .336$
	Experimental	4.80 (2.25)	5.68 (2.38)						
Presenting info	Control	3.15 (1.52)	2.67 (1.72)	$F_{1,78} = 2.05$, $p = .156$, $\eta^2_{partial} = .026$	$F_{1,78} = 1.04$, $p = .312$, $\eta^2_{partial} = .013$	$F_{1,78} = 4.17$, $p = .045$, $\eta^2_{partial} = .051$	$F_{3,47046} = 0.59$, $p = .620$	$F_{1,78} = 0.14$, $p = .713$	$F_{1,78} = 0.70$, $p = .405$
	Experimental	3.64 (1.58)	3.56 (1.61)						
IPS process	Control	30.75 (9.85)	30.47 (12.89)	$F_{1,78} = 10.01$, $p = .002$, $\eta^2_{partial} = .114$	$F_{1,78} = 11.57$, $p = .001$, $\eta^2_{partial} = .129$	$F_{1,78} = 6.86$, $p = .011$, $\eta^2_{partial} = .081$	$F_{3,47046} = 0.01$, $p = .998$	$F_{1,78} = 0.05$, $p = .816$	$F_{1,78} = 0.33$, $p = .570$
	Experimental	33.24 (12.89)	41.08 (12.77)						
SES-IB-16	Control	52.60 (10.30)	53.87 (10.87)	$F_{1,78} = 25.27$, $p < .001$, $\eta^2_{partial} = .245$	$F_{1,78} = 16.08$, $p < .001$, $\eta^2_{partial} = .171$	$F_{1,78} = 6.87$, $p = .011$, $\eta^2_{partial} = .081$	$F_{3,47046} = 0.93$, $p = .425$	$F_{1,78} = 1.15$, $p = .288$	$F_{1,78} = 3.37$, $p = .070$
	Experimental	52.87 (8.59)	64.28 (8.27)						

Mixed ANOVA. In the case of the skill *Defining research questions*, there is an intra-subject effect [$F_{1,78} = 5.36$, $p = .023$, $\eta^2_{partial} = .064$], but there is no interaction between this factor and the group (see Table 2). According to Cohen (1992), the effect size ($\eta^2_{partial}$) is low for .01, medium for .06, and large for .14. In the case of the intra-subject effect, it has an average size. For the training applied to be effective, the interaction between the two factors must be given. Therefore, as it is not given, its effectiveness is rejected. Although there is no interaction, the treatment can be considered effective if the pattern found is as expected. A mean difference test was applied to see with which of the four means in Figure 4a statistically significant differences could be found. There are only differences between the pre and post means for the experimental group [*Bonferroni* = 1.24, p = .020], resulting in an increase in the dependent variable in the post measure in this group, and not changing the pre and post measures in the control group, which would indicate that the pattern is as expected. Finally, we also found no inter-subject effect depending on the group (experimental or control).

Figure 4. Means for pre and post measures for the two groups (experimental and control)



In relation to the skill *Planning search strategies*, there is an intra-subject effect [$F_{1,78} = 7.83$, $p = .006$, $\eta^2_{partial} = .091$], and also interaction between this factor and the group [$F_{1,78} = 9.07$, $p = .004$, $\eta^2_{partial} = .104$] (see Table 2), with a medium-high effect size. That means the training was quite effective. If we compare the four means in Figure 4b, we can conclude that there are (a) differences between the pre-test and post-test measures of the experimental group [*Bonferroni* = 2.96, p = .001], with a higher score in the second measure, and (b) differences between the control group and the experimental group for the post-test measure [*Bonferroni* = 4.22, p < .001], with a higher score for the latter group. Therefore, the results clearly support the effectiveness of the training. Finally, there is an inter-subject effect depending on the group [$F_{1,78} = 10.18$, $p = .002$, $\eta^2_{partial} = .115$], with a higher score for the experimental group, as expected.

In the skill *Searching and locating sources*, we find the same pattern: there is an intra-subject effect [$F_{1,78} = 13.08$, $p = .001$, $\eta^2_{partial} = .114$], and interaction between this factor and the group [$F_{1,78} = 10.38$, $p = .002$, $\eta^2_{partial} = .117$] (see Table 2), with a medium-high effect size. Therefore, in this case, the training was also effective. If we compare the differences between the four means of Figure 4c, we obtain the expected pattern: there are differences between the pre and post measures of the experimental group [*Bonferroni* = 2.84, p < .001], with a higher score in the second measure, and between the control and experimental groups for the post measure [*Bonferroni* = 3.24, p = .001], with a higher average for the experimental group. Finally, there is an inter-subject effect depending on the group [$F_{1,78} = 6.69$, $p = .012$, $\eta^2_{partial} = .079$], with a higher score for the experimental group.

In the case of the skill *Selecting and processing information*, there is no contrasted effect (see Table 2), so it can be considered that the training was not effective. Despite this, the pattern is as expected, as can be seen in Figure 4d: the experimental group increases its average score compared to the control group, which does not change, although this increase is not statistically significant.

Regarding the skill *Presenting information*, there is no intra-subject effect or interaction between this factor and the group (see Table 2), so we can consider that the training has not been effective. In addition, in Figure 4e it can be seen that the pattern is not as expected: with a decrease in the post scores for the control and experimental groups. There are significant differences between the pre and post measures for the control group [*Bonferroni* = 4.73, p = .031], with a higher score for the pre measure, which is an unexpected result. There is also a higher average for the experimental group compared to the control group in the post measure [*Bonferroni* = 0.89, p = .032], an expected pattern in this case. Finally, there is an inter-subject effect depending on the group [$F_{1,78} = 6.86$, $p = .011$, $\eta^2_{partial} = .081$], which indicates that the experimental group does not change its mean over time while the control group gets worse.

In relation to general ability, in the whole *IPS process* there is an intra-subject effect [$F_{1,78} = 10.01$, $p = .002$, $\eta^2_{partial} = .114$], and interaction between this factor and the group [$F_{1,78} = 11.57$, $p = .001$, $\eta^2_{partial} = .129$] (see Table 2), with a medium-high effect size, so we can conclude that the training was quite effective. If we compare the differences between the four means in Figure 4f, we obtain the expected pattern: there are differences between the pre and post measures of the experimental group [*Bonferroni* = 7.84, p < .001], with a higher score in the second measure, and between the control and experimental groups for the post measure [*Bonferroni* = 3.10, p = .001], with a higher average for the experimental group. Finally, there is an inter-subject effect depending on the group [$F_{1,78} = 6.86$, $p = .011$, $\eta^2_{partial} = .081$], with a higher score for the experimental group.

In the case of the *self-efficacy expectations* measured by the SES-IB-16, we observe that there is an intra-subject effect [$F_{1,78} = 25.27$, $p < .001$, $\eta^2_{partial} = .245$], and interaction between this factor and the group [$F_{1,78} = 16.08$, $p < .001$, $\eta^2_{partial} = .171$] (see Table 2), with a high effect size, so the training was very effective. If we compare the differences between the four means in Figure 4g, we observe that the expected pattern is given: there are differences between the pre and post measures of the experimental group [*Bonferroni* = 11.32, p < .001], with a higher score in the second measure, and between the control and experimental groups for the post measure [*Bonferroni* = 10.41, p = .001], with a higher average for the experimental group. Finally, there is an inter-subject effect depending on the group [$F_{1,78} = 6.87$, $p = .011$, $\eta^2_{partial} = .081$], with a higher score for the experimental group.

4. Discussion

In the present research, we evaluated the effectiveness of a task-centred IPS course on reviewing scientific literature. The study measured both IPS skills development and self-efficacy. After the online course, significant differences were found between the experimental and control groups, with a medium-high effect size in the skills *Planning search strategies*, *Searching and locating sources*, and in the whole *IPS process*. In addition, a trend pattern was perceived in the skills *Defining research questions* and *Selecting and processing information*. Unfortunately, no changes were found for the skill related to *Presenting information*. Furthermore, the experimental students developed a significant change in self-efficacy expectations regarding their IPS skills.

Our first research question was 'Does task-centred instruction improve the IPS skills needed to carry out an academic literature review task in an online higher education environment?' In the following paragraphs, we discuss the impact of the task-centred course in each constituent IPS skill and in the IPS process.

With regard to the skill *Defining research questions* (i.e., analysis of the topics, activating prior knowledge, and establishing the research questions according to the selected topic), differences were found between the experimental and control groups, but they were not statistically significant. This result is in line with that of Frerejean, Velthorst et al. (2019), who pointed out that activities related to defining the problem were scarce. Three possible reasons might explain our findings.

First, during the instruction, students were asked to create a mind map to understand the problem and activate their prior knowledge in order to generate adequate research questions. On the one hand, students diverged enormously in their prior knowledge, so the action of creating the mind map could be difficult to instruct, although different options and possibilities were provided during the class. On the other hand, students were very preoccupied and busy creating their mind maps, which could cause a lack of time for generating relevant questions, an essential starting point for well-conducted searches (Argelagós & Pifarré, 2016; Brand-Gruwel et al., 2005). Further research should include an improvement in this point of instruction.

Second, this skill implies a variety of activities that can be carried out in different ways, and the pre- and post-tests could not collect all of them (Garcia et al., 2020; Rosman et al., 2016b). In future studies, additional techniques to collect data about defining the research question should be included to gather in a more comprehensive way the activities related to this skill, such as log files to record the actions made on the computer by each student, self-reports, or other techniques (see Argelagós et al., 2018; Kammerer et al., 2018).

Third, one has to take into account that during the IPS process the execution of one constituent skill gives feedback in order to accomplish the other ones. Because of this, the research question sometimes emerges after several 'rounds' of search and review activities. The IPS process is iterative and implies going back and forth between different constituent IPS skills (Garcia & Badia, 2017). In this case, the skill *Defining research questions* might have been affected by the information obtained by other constituent IPS skills, such as *Searching and locating sources* and *Selecting and processing information*. Further research should focus more on the iterative nature of IPS. Even so, in this study, when comparing the experimental and control groups, the average trend in the *Defining research questions* skill was as expected.

Regarding the two skills related to searching the sources: *Planning search strategies* (i.e., determining the information needed, specifying the appropriate search terms, selecting a search strategy) and *Searching and locating sources* (i.e., executing searches in Google Scholar and databases, using thesauruses, keywords, and Booleans, assessing the results and sources), instructed students obtained significantly better scores than uninstructed ones. These activities were more covered during the pre- and post-tests and are central to IPS in information literacy instruction. This finding reflects the results obtained by Argelagós and Pifarré (2012) and Raes et al. (2012), who also found a better performance in secondary students trained with an IPS instruction, and by Leichner et al. (2014), Squibb and Mikkelsen (2016), and Rosman et al. (2018) in higher education.

Turning to the skill *Selecting and processing information* (i.e., selecting sources, critically evaluating information, choosing and storing relevant information, comparing and contrasting information), no statistically significant changes were found in our study, although we detected an expected change tendency, in which experimental students obtained better scores than control ones. These results might be explained by the need for more time for instruction (Frerejean, Velthorst et al., 2019), as well as a high level of effort and motivation (Brante & Strømsø, 2018), since it is an essential skill to obtain success in an IPS task (Barzilai et al., 2018).

Similarly, the activities related to the skill *Presenting information* (planning the text, using the information processed, and putting it together correctly in the text: paraphrasing, quoting, in-text citations, references) obtained a better mean score, but not one of statistical significance. In addition to the reason given for the previous skill (more time needed for instruction), other specific academic writing abilities not considered in our instruction are necessary in order to present a higher-quality product (Castelló et al., 2009; Swales & Feak, 2004).

Regarding the whole *IPS process*, significant statistical differences were found between the experimental and the control group. More specifically, the instruction in the experimental condition was efficient and effective, which resembles the results of previous studies (Frerejean, Velthorst et al., 2019; Wopereis et al., 2015).

The second research question of our study was ‘What is the effect of task-centred instruction on IPS self-efficacy expectations?’ In this regard, the results of the self-assessment instrument, the SES-IB-16, reveal a high satisfaction among the experimental students. According to Rosman et al. (2015), self-assessments of information literacy correlate higher with actual ability in information literacy, and are a good instrument if measured after the administration of information search tasks, as a complement to the objective tests (Gross & Latham, 2012), as the former can measure aspects that are difficult to examine for the latter (Falchikov, 2005; Oscarson, 1989).

In sum, IPS-instructed students obtained significantly better scores in the skills *Planning search strategies* and *Searching and locating sources*, as well as a positive trend pattern in the skills *Defining research questions* and *Selecting and processing information*. However, no changes were found for the skill *Presenting information*. The general, whole *IPS process* also showed significant changes in pre-test and post-test measures. Furthermore, students in the experimental group developed a significant positive change in self-efficacy related to IPS.

4.1. Limitations

Some potential limitations should also be considered in our study. First, the current online course was informed by the 4C/ID model, which means it applied some important instructional design guidelines. For instance, as regards the learning tasks, this model proposes that they are based on authentic, real-life situations. In addition, the 4C/ID suggests two types of built-in tasks (Frerejean et al., 2016), but our study did not consider them: the *completion strategy* (Van Merriënboer & De Croock, 1995), which consists in removing parts of the solution as a way of training, starting with the last parts to be completed; and *emphasis manipulation* (Gopher et al., 1989), which stresses one aspect of the skill during a learning task in order to diminish the cognitive demand. Cultural and time constraints led us to design the instructional course by following the skills in a logical order (instead of the completion strategy) and dealing with an entire skill during each session (instead of the emphasis manipulation strategy). Future research should be conducted considering these strategies in order to contain enough built-in task guidance and support to assist the students (see Van Merriënboer & Kirschner, 2018).

Second, the instruction carried out was not embedded, but it was offered by means of a standalone library training, since it was a pilot and voluntary course. Previous research on IPS shows that this kind of instruction can obtain positive effects (Gerjets & Hellenthal-Schorr, 2008; Hämäläinen et al., 2020; Walton & Helworth, 2011). However, other studies point out that curriculum-embedded instruction seemed more effective, at the primary level (e.g., De Vries et al., 2008; Kuiper et al., 2008; Spink et al., 2010; Wang et al., 2012), secondary level (Argelagós & Pifarré, 2012; Kammerer et al., 2016; Raes et al., 2012; Pifarré & Argelagós, 2020), and in higher education (Brand-Gruwel & Wopereis, 2006; Rosman et al., 2016a; Squibb and Mikkelsen, 2016; Wopereis et al., 2008; Wopereis et al., 2015, 2016).

Third, the number of participants differed substantially between the two groups (experimental group: n=25; control group: n=55). Initially, the experimental group included 120 students. However, due to the design principle of performance constraints (Van Merriënboer & Kirschner, 2018), many students dropped-out as they were not allowed to proceed because they had not mastered the constituent IPS skills necessary to adequately perform earlier steps in the IPS process. This led to a pronounced reduction in the number of students in the experimental condition, but guaranteed the quality of learning of the students within that group.

Fourth, our study showed good results in the general process of IPS and in self-assessment. However, the long-term effects of the intervention are unknown due to the lack of a delayed post-test. For instance, Frerejean, Velthorst et al. (2019) pointed out that the improvements among instructed secondary students in comparison with uninstructed ones in an embedded whole-task IPS instruction were only visible in the post-test and disappeared in the delayed post-test. Further research on IPS instruction including delayed post-test is warranted.

4.2. Implications for practice and research

In general, this study shows that a task-centred IPS instruction informed by 4C/ID to develop the cognitive skills needed to perform an academic literature review task in higher education can potentially be effective. However, we recommend embedded whole-task IPS instruction, completely based on 4C/ID, as explained in the limitations section. In addition, some of the skills taught within an educational programme should benefit from more opportunities for practice over a longer period (Ericsson et al., 1993; Frerejean, Van Merriënboer et al., 2019; Wopereis et al., 2016), specifically the skills *Defining research questions*, *Selecting and processing sources*, and *Presenting information*.

During our instructional process, there were two critical elements, derived from the 4C/ID model: modelling examples and prompt individual feedback.

- On the one hand, modelling example videos – screen recordings that display the actions made on the computer by a model and an oral transcription of her thoughts – were used to show how an expert conducted a learning task. This is highly recommended because the learners are provided with a model to follow (see Costa et al., 2021; Frerejean et al., 2018) instead of making attempts that could amount to a waste of time (Kirschner et al., 2006). However, modelling examples can be improved by using eye-movement modelling examples (EMMEs), which are videos that include a dot representing the eye movements in the modelling example videos. Experiences in clinical settings showed a better guidance of the students' attention towards the relevant features of a diagnosis in complex perceptual tasks (Jarodzka et al., 2012). In an educational context, Salmerón and Llorens (2019) showed the effectiveness of EMMEs with ninth-grade students asked to plan, evaluate, and monitor their digital reading.

- On the other hand, extensive and individual feedback (Peter et al., 2017) provided promptly represented a fundamental aspect for helping students to detect their weaknesses and solve their doubts. Feedback has a strong impact on cognitive skills and has become a focus of teaching research and practice (Hattie & Timperley, 2007; Wisniewski et al.2020). Prompt feedback has been considered a success factor of effective and efficient instruction in previous studies reporting IPS instruction in higher education (Wopereis et al., 2016). In addition, regulation feedback is another possible way of providing feedback (Dochy et al., 1999), as shown in studies with teenagers learning IPS skills to search for information online (Timmers et al., 2015).

As regards research implications, we collected the data of the pre- and post-tests, but we did not gather information about the process throughout the intervention. It could be very interesting to also observe the instructional process, which can be done by means of complementary techniques, such as log files, eye-tracking, and cued-retrospective reports (see Argelagós et al., 2018), in order to apprehend in a deeper and/or qualitative way the strengths and weaknesses of the instructions and how to improve or complete them (Frerejean, Velthorst et al., 2019).

In addition, as a future line of work, the iterative nature of the skills could be a necessary point to delve into. There is a need to emphasize iterativity and reflection in current IPS models. For instance, regarding the skill *Presenting information*, the academic writing skill is worth analysing in more detail and could benefit from research on reflective writing. See for instance the research of Schön (1983) on reflective practices and Gibbs' (1988) work on the 'reflective cycle'.

5. Conclusions

This study has showed that online task-centred IPS instruction, informed by the 4C/ID model, has potential for developing IPS skills to conduct an academic literature review task in higher education, and has detected areas where such instruction can be enhanced. The article has presented a quasi-experimental study to analyse the effect of instruction on the IPS skills and IPS self-efficacy expectations of graduate students. The goal of the article was to find answers to the following two research questions:

Research Question 1 asked about whether a task-centred instruction improves the IPS skills needed to carry out an academic literature review task in an online higher education environment. It was found that the experimental group improved statistically (or as a positive trend) in most of the constituent IPS skills and in the IPS process, in comparison with the control group. Thus, the main conclusion is that the five constituent IPS skills as well as the IPS process can be learned, instructed, and improved by well-designed task-centred instruction informed by the 4C/ID model.

Research Question 2 focused on the effect of task-centred instruction on IPS self-efficacy expectations. Our study shows that the experimental students also attained greater satisfaction than their control counterparts, which demonstrates the positive effect of the instruction on the development of the IPS skills needed to enable graduate students to perform an academic literature review task and therefore to contribute to enhancing the quality of science and education.

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