Information Problem Solving Instruction in Higher Education: A Case Study on Instructional Design

Iwan Wopereis(✉), Jimmy Frerejean, and Saskia Brand-Gruwel

Faculty of Psychology and Educational Sciences,
Open University of the Netherlands, Heerlen, The Netherlands
{iwan.wopereis, jimmy.frerejean,
saskia.brand-gruwel}@ou.nl

Abstract. Information problem solving (IPS) is the process of locating, selecting, evaluating, and integrating information from various sources to fulfill an information need. In academia, it is central to conducting literature reviews in research projects. This paper presents a case study on effective and efficient instructional design for learning this complex skill. It includes an analysis of students' output and (perceived) studiability of an online IPS-course that was designed according to the 4C/ID-model, a contemporary holistic instructional design model. Results were based on data retrieved from 49 Open University premaster students. The results show that a holistic approach to instructional design is effective: all students passed the course and they appreciated course studiability. However, due to the holistic ('whole task') design approach, the students' time on task was relatively high as was the time teachers spent on providing instructional support, which questions efficiency.

Keywords: Instructional design · Information problem solving · Information literacy · Completion strategy · Whole-task models · 4C/ID-model

1 Introduction

Information problem solving (IPS), a term that is similar to information literacy [1, 2], is a vital skill for academics. It is central to research and learning, two critical constituents of academic proficiency. IPS entails processes that involve locating, selecting, evaluating, and integrating information from various sources and is initiated to fulfill an information need [3–7]. Although IPS is widely acknowledged to be pivotal to academic work, formal IPS instruction has long been an insignificant element of curricula in higher education. In the past, IPS-instruction was often added as an appendage to curricula, for instance by means of a set of tutorials each focusing on learning distinct IPS-constituents. In the last decade or two, these 'part-task' instructional materials were gradually replaced by more extensive programs that included meaningful, domain-related, 'whole-task' learning activities (see e.g., [8–10]). Although these programs were increasingly integrated into curricula, they were often too small to include a *variety* of such whole, authentic IPS-tasks, necessary for transfer of learning [11].

S. Kurbanoğlu et al. (Eds.): ECIL 2015, CCIS 552, pp. 293–302, 2015.
DOI: 10.1007/978-3-319-28197-1_30

In 2012, the Open University of the Netherlands (OUNL) noticed that a substantial group of students aspiring to pursue a master's program in Educational Sciences lacked basic IPS skills necessary to conduct educational research projects. Existing bachelor-level IPS instruction was judged insufficient and, therefore, a new premaster's course was designed. This course was based on the latest insights on instructional design for complex learning. Merrill [12], who analyzed various contemporary instructional design models to derive a series of basic principles for designing instruction, concluded that the Four-Component Instructional Design model (4C/ID-model) of Van Merriënboer [11, 13–16] was one of the most comprehensive instructional models for complex learning. Therefore, it was decided to use the 4C/ID-model to design the IPS-course for premaster's students.

The result of applying the 4C/ID-model is an instructional blueprint that includes four components. The first component refers to *learning tasks* that are based on authentic or 'real-life' tasks. They form the backbone of an instructional program. A varied set of learning tasks facilitates a process called inductive learning. The second component consists of *supportive information*. This information is necessary to carry out the non-routine aspects of learning tasks and is acquired through elaboration and understanding. The third component comprises *procedural information* that enables learners to perform the routine aspects of learning tasks. It is the result of a process called knowledge compilation. The fourth component is *part-task practice* that consists of the training of routine parts of the task that need to be automated. This is done by a process called strengthening.

We decided that the new course would focus on the skill of 'Conducting a literature review', a complex IPS-skill that is at the heart of academic work. Due to time limits (this was a 120-h course) we decided to limit the level of complexity and provide the students with a confined set of learning tasks. We elaborate further upon the instructional blueprint for the course in the method section and Appendix 1.

The aim of the case study is to show that a holistic approach to instructional design (i.e., 'whole task'-centered design as presented by the 4C/ID-model) is suitable to design effective and efficient IPS-instruction. We analyzed students' output (i.e., grades) and students' perceptions of the quality of course components (i.e., studiability) in order to explore the effectivity of the course (i.e., 'Did it hit the target?'). Additionally, we explored students' time on task to make inferences about instructional efficiency (i.e., 'Was it the shortest route to the goal?').

2 Method

2.1 Participants

Students (n = 49; 8 male) of the Educational Sciences pre-master's program of OUNL followed a 4.3 EC (120-h) online course on conducting a systematic literature review called 'Information skills for social scientists' (code O40). This course is part of a transitions program that consists of a series of methodology, academic, and domain-specific skill courses that prepare aspiring master's students holding a professional bachelor degree for admission to the master's program. Students enrolled in the course individually at various times across the academic year 2013–2014. For this study we selected students who finished the course in 2014.

2.2 Materials

Course O40. The ‘Information skills for social scientists’ course (code O40) aims at teaching students the fundamentals of conducting a literature review. The 4C/ID-model was used to design this course of which the structure is presented in Fig. 1.

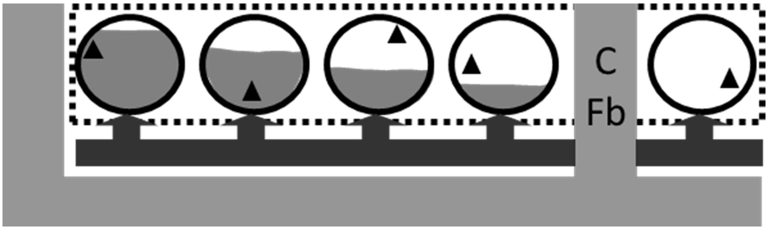

Fig. 1. Representation of Course O40 that comprises learning tasks (circles), supportive information (grey beam), and procedural information (black beam with upward pointing arrows).

Appendix 1 elaborates on this figure and presents a simplified design blueprint of the main components of the course that we briefly discuss in this section. The backbone of the course is a set of five learning tasks that is based on authentic, real-life literature review tasks in the domain of Educational Sciences. This is ‘a task class’; the dotted box in Fig. 1 comprises the learning tasks. The complexity level of this task class is basic: students’ topic familiarity for all tasks is relatively high, topics are well-researched within the domain, and the type of review central to all tasks is relatively simple (i.e., a traditional and systematic review instead of a meta-analysis, see [17]). Due to preconditions related to course design like time on task (i.e., 120 h study load), learning tasks are simplified: for each task students select a limited number of journal articles and write a concise review of a maximum of 600 words.

In order to enhance inductive learning (i.e., schema construction), the task class comprises five different tasks of the same complexity level. These are seen as the five circles in Fig. 1; variability is represented by small triangles within each circle. The selected review topics are ‘Outlining as learning tool’ (Learning Task 1), ‘Multimedia learning’ (Learning Task 2), ‘Student evaluations’ (Learning Task 3), ‘Cooperative learning’ (Learning Task 4), and ‘Self-regulated learning’ (Learning Task 5). Although these five learning tasks introduce the learner to the whole review task, the instructional emphasis within each task differs (see Table 1). In Learning Task 1 the whole process of conducting a literature review is *demonstrated* to the learner in order to get a first overview of all constituents of conducting a literature review. These constituents relate to five main steps in the review process, namely (1) defining the research question(s), (2) searching sources, (3) selecting sources, (4) processing information, and (5) presenting information. In Learning Task 1 students study a video-recorded modeling example that presents an expert who performs all steps. Students also study the (semi-manufactured) products of steps such as a summary table of selected resources (product step 3) and the final review article (product step 5). As can be seen in Table 1, students gradually learn to execute more steps of the review process themselves in Learning Tasks 2 to 5. In Learning Task 2 they perform steps 4 and 5 based on information from steps 1 to 3 that is provided to them. In Learning Task 3 they perform steps 3 to 5, based on steps 1 and 2. In Learning Task 4 the students execute steps 2 to 5 based on a research question that is presented to them (step 1). Finally, in Learning Task 5 they perform all steps of the review process. The students formulate a research question and after approval (and receiving feedback on this step) they continue working on the learning task. Learning Task 5 serves as assessment task.

Table 1. Course overview

	Learning Task 1	Learning Task 2	Learning Task 3	Learning Task 4	Learning Task 5
Define question(s)	Worked-out	Worked-out	Worked-out	Worked-out	Execute*
Search for sources	Worked-out	Worked-out	Worked-out	Execute*	Execute
Select sources	Worked-out	Worked-out	Execute*	Execute	Execute
Process information	Worked-out	Execute*	Execute	Execute	Execute
Present information	Worked-out*	Execute	Execute	Execute	Execute

*= focus of instruction

Learner support –indicated by the grey filling in the circles in Fig. 1– gradually diminishes from 'high' in Learning Task 1 (modeling example), via Learning Tasks 2, 3, and 4 (completion tasks) to 'low' in Learning Task 5 (conventional task). This so-called 'completion strategy' has been found to have positive effects on inductive learning and transfer [18]. Students gradually perform more steps of the review process, starting with the last steps. In every subsequent learning task they have to perform an additional (previous) step of the original review process. This instructional guidance strategy is called 'backward fading' [19].

Supportive information is necessary to learn the non-recurrent aspects of the learning tasks. It includes cognitive strategies, mental models, and cognitive feedback. In Fig. 1 it is specified as an L-shaped shaded area. Important cognitive strategies are the systematic approaches to problem solving (SAPs). The aforementioned five steps constitute the main SAP of conducting a literature review (see Table 1). Mental models include conceptual models, structural models, and causal models. Examples of mental models in this course are conceptual models of literature review concepts and how scientific articles are organized, and structural models of how databases are organized and can be used. Cognitive feedback focuses on the quality of task performances and specifically aims at improving the non-recurrent aspects of the task. In this course students receive extensive feedback on task performance after finishing Learning Task 4 (see CFb in Fig. 1). Supportive information is offered to the students by means of video instruction and text books [17, 20] and has been tailored to the task. This means that the delivery of supportive information is coupled to the steps that are emphasized in each learning task (see * in Table 1).

Procedural information relates to the recurrent aspects of the learning tasks. It consists of rules that should be learned at the time students need to perform the task ('just-in-time', see the black beam with upward pointing arrows in Fig. 1). For Learning Task 2 procedural information includes the procedures for academic writing [21]. Procedural information for Learning Task 3 includes procedures (i.e., tutorials) needed to operate a search program and use a thesaurus. For this course no part-task practice was specified.

The online course is presented to the students in OpenU, a contemporary digital learning and working environment of the OUNL [22]. Beside the learning tasks, supportive information, and procedural information, the OpenU system offers the students and teachers a monitoring system and Web 2.0 facilities to guide and support the learning process.

SEIN Questionnaire. The SEIN questionnaire is a course evaluation instrument at the OUNL [23]. After each course OUNL-students are requested to fill in the SEIN questionnaire. It consists of multiple choice, rating, and open questions that record student perceptions of course quality (e.g., studiability, feasibility, and practicability), and time on task. Rating questions focus on the (perceived) quality of course constituents, instructional guidance, and instrumental support. Open questions aim at revealing strengths and weaknesses of these elements.

2.3 Procedure

Students followed the online course individually and at their own pace through OpenU. Both formative and summative feedback were provided to the students via this system. Data related to both type of assessments were obtained from the system. Invitations to fill in the electronic SEIN questionnaires were sent to each student after finishing the course. Data were provided to the researchers by an educationalist responsible for SEIN.

3 Results

All students passed the summative assessment task (Learning Task 5). The average grade for this task was 6.98 (SD = .93). Mode and median were both 7 and the scores ranged from 6 to 10. The skewness of scores was 1.024, which means that the shape of the distribution of scores is skewed right.

Beside the summative assessment of the IPS-skill, students were assessed formatively. Results of the formative assessment provided after Learning Task 4 show that students had difficulty deriving search terms and synonyms from a research question, finding relevant information in scientific sources, and writing a concise essay.

Most students needed the additional cognitive feedback (CFb in Fig. 1). An analysis of the formative assessment on the formulation of a research question for Learning Task 5 shows that students needed additional instructional support on defining the research (review) question as well. The scope of the topic selected by students was often too broad.

Students' perceived course quality focused on several components of the course design. Table 2 shows that average ratings for components were encouraging as was the overall course rating. Course components such as the learning tasks, the assessment task, the supportive information, and cognitive feedback were highly rated. The latter was especially well-received. This result was validated by several comments made in the SEIN questionnaire: "Feedback was to the point, clear, useful, and appropriate", "Superb teacher feedback", and "The feedback is constructive and informative". Despite this, some students would have liked to receive cognitive feedback in an earlier stage of the course.

Table 2. Ratings (n = 48) for course components (scale 1 to 10; 1 = poor, 10 = excellent)

Focus	Mean	SD	Mode	Skewness
Course, overall rating	7.44	.94	8	−.53
Learning tasks	7.35	1.10	7	−.46
Assessment task (Learning task 5)	7.57	1.04	8	−.51
Supportive information (theory/books)	7.06	1.12	7	−1.46
Teacher support (i.e., cognitive feedback)	7.90	1.28	9	−.25
Digital learn and work environment	7.42	.90	7	.34
Forum	6.15	1.46	7	−1.32

With regard to the course content students indicated that it met the learning goals (100 % score, see Table 3). Also the nature of the course was applauded. Table 3 shows the percentages for agreement on practical and scientific level and challenge.

Table 3. Opinion (n = 48) on global course features

Focus (yes/no question)	Yes (%)
Practical level of the course is adequate	98
Scientific level of the course is adequate	98
Course is challenging	81
Learning goals are met	100

The 'time on task' for completing the course was estimated by students and categorized into five categories. 10.42 % of the students needed less than 75 h to complete the course. 14.58 % spent between 75 and 100 h to complete the course. 35.42 % needed between 100 and 125 h for the course. 27.08 % spent between 125 and 150 h for the course, and 12.50 % needed more than 150 h. This means that approximately 40 % of the students needed more 'time on task' than the estimated 120 h of study.

4 Discussion

This case study explored the quality of an information literacy course in higher education. Our aim was to show that a holistic instructional design approach (i.e., 4C/ID) is suitable to develop effective and efficient instruction for learning to conduct a literature review. Confirmed by the output of our course we can argue that 'whole task'-centered instruction is effective: no students failed the course and the average grades were good, meaning that all students reached a basic skill level. Also, the students' perceived quality of the course components that feature the 'whole-task approach' (i.e., a series of 'whole' learning tasks that constitute the backbone of the course) confirms the effectiveness of using the 4C/ID-model to design instruction for learning complex skills like conducting a literature review. Emphasizing whole task learning and using a rigorous scaffolding method to learn a series of varied tasks thus yields a desired learning profit [11–16]. An important question is whether the instructional design for the O40-course is not only effective, but also efficient. Based on an analysis of the time on task it can be concluded that the instructional blueprint resulted in learning tasks which were time-consuming for a substantial number of students. About 40 % of the students needed more time than was estimated to finish the course. Study feasibility can thus be negatively influenced when insufficient study time is allocated to task performance. Therefore, instructional designers should realize that an important precondition for developing good quality instruction for complex learning includes offering sufficient time to complete a series of varied whole tasks. A suggestion for a redesign of the O40-course could be to (re)allocate additional time to the learning tasks that include more execution steps.

Another success factor of effective and efficient instruction is the fact that cognitive feedback is provided on time [24]. To a large extent the quality and quantity of the cognitive feedback in the O40-course has been warranted (e.g., after Learning Task 4). However, students indicate that more 'just-in-time' cognitive feedback is wished for (i.e., after Learning Tasks 1 to 3). For the instructional designers it is a challenge to design cognitive feedback for (whole) task-centered learning that is less time extensive for the teacher. Peer feedback and/or worked-out feedback might be solutions.

In this case study we analyzed a basic bachelor-level IPS-course. We used 4C/ID principles to successfully design the course. These results are encouraging but need to be 'scaled up'. For students to learn the literature review skill at high-level it is necessary to design a longitudinal learning trajectory that includes several courses (i.e., task classes) that should address skill learning at increasing complexity levels as well (i.e., master's/Ph.D.). Future research should aim at scrutinizing the design, development, implementation, and evaluation of such a longitudinal learning track. Design-based research could be a helpful approach to address this issue [25].

Appendix 1: Blueprint Course O40

Simplified blueprint for the pre-master's course 'Information Skills for Social Scientists' (O40). It includes an overview of the components that make the course: (a) learning tasks, (b) supportive information, and (c) procedural information.

<table>
<tr><td colspan="2">Task class (basic level): In order to learn the basics of performing a literature review, students carry out five learning tasks. Topic familiarity is high for each task. Students must select a relatively small set of key articles and the essay that concludes each task may not exceed 600 words.</td></tr>
<tr><td colspan="2">Supportive information: present cognitive strategies

• Systematic approach to problem solving (SAP) of the five steps involved in performing a literature review: (1) define research questions, (2) search for sources, (3) select sources, (4) process information, and (5) present information.</td></tr>
<tr><td colspan="2">Supportive information: present mental models

• Conceptual model of literature review concepts.
• Structural model of how databases are organized and can be used.
• Conceptual model of scientific articles and how they are organized.</td></tr>
<tr><td colspan="2">Supportive information: cognitive feedback

• Feedback related to the SAP and domain models</td></tr>
<tr><td>Learning task 1: Modelling example / Worked out example

Demonstration Step 1 until 5 by an expert. Students study the example. Emphasis is on all phases of the SAP</td><td></td></tr>
<tr><td>Learning task 2: Completion

Demonstration Step 1 to 3; Students perform Step 4 and 5. Emphasis is on Step 4 of the SAP</td><td>Procedural information presentation:

• Procedures for academic writing (cf. Publication Manual of the American Psychological Association)</td></tr>
<tr><td>Learning task 3: Completion

Demonstration Step 1 and 2; Students perform Step 3, 4, and 5. Emphasis is on Step 3 of the SAP</td><td>Procedural information presentation:

• Procedures for academic writing (cf. Publication Manual of the American Psychological Association)(fading)</td></tr>
<tr><td>Learning task 4: Completion
Demonstration Step 1; Students perform Step 2, 3, 4, and 5. Emphasis is on Step 2 of the SAP</td><td>Procedural information presentation:
• Procedures for operating the search program (part of Step 2)
• Procedures for using a thesaurus (part of Step 2)</td></tr>
<tr><td>Learning task 5: Conventional
Students perform all steps. Emphasis is on Step 1 of the SAP. The research question has to be approved before a student continues the IPS-process.</td><td>Procedural information presentation:
• Procedures for operating the search program (fading)
• Procedures for using a thesaurus (fading)</td></tr>
</table>

References

1. Association of College & Research Libraries: Information Literacy Competency Standards for Higher Education. ACRL, Chicago (2000)
2. Virkus, S.: Information literacy in Europe: a literature review. Inf. Res. **8**(4), paper no. 159 (2003)
3. Brand-Gruwel, S., Wopereis, I.: Integration of the information problem-solving skill in an educational programme: the effects of learning with authentic tasks. Technol. Instr. Cogn. Learn. **4**, 243–263 (2006)
4. Brand-Gruwel, S., Wopereis, I., Vermetten, Y.: Information problem solving by experts and novices: analysis of a complex cognitive skill. Comput. Hum. Behav. **21**, 487–508 (2005)
5. Brand-Gruwel, S., Wopereis, I., Walraven, A.: A descriptive model of information problem solving while using internet. Comput. Educ. **53**, 1207–1217 (2009)
6. Wopereis, I., Brand-Gruwel, S., Vermetten, Y.: The effect of embedded instruction on solving information problems. Comput. Hum. Behav. **24**, 738–752 (2008)
7. Wopereis, I.G.J.H., Van Merriënboer, J.J.G.: Evaluating text-based information on the world wide web. Learn. Instr. **21**, 232–237 (2011)
8. Birkett, M., Hughes, A.: A collaborative project to integrate information literacy skills into an undergraduate psychology course. Psychol. Learn. Teach. **12**, 96–100 (2013)
9. Larkin, J.E., Pines, H.A.: Developing information literacy and research skills in introductory psychology: a case study. J. Acad. Libr. **31**, 40–45 (2005)
10. Mullins, K.: Good IDEA: instructional design model for integrating information literacy. J. Acad. Libr. **40**, 339–349 (2014)
11. Van Merriënboer, J.J.G., Kirschner, P.A.: Ten Steps to Complex Learning: a Systematic Approach to Four-Component Instructional Design, 2nd edn. Routledge, New York (2013)
12. Merrill, M.D.: First principles of instruction. Educ. Technol. Res. Dev. **50**(3), 43–59 (2002)
13. Van Merriënboer, J.J.G.: Training Complex Cognitive Skills: a Four-Component Instructional Design Model for Technical Training. Educational Technology Publications, Englewood Cliffs (1997)
14. Van Merriënboer, J.J.G.: Alternate models of instructional design: holistic design approaches and complex learning. In: Reiser, R.A., Dempsey, J.V. (eds.) Trends and Issues in Instructional Design and Technology, pp. 72–81. Pearson/Merrill Prentice Hall, Upper Saddle River (2007)
15. Van Merriënboer, J.J.G., Clark, R.E., De Croock, M.B.M.: Blueprints for complex learning: the 4C/ID-model. Educ. Technol. Res. Dev. **50**(2), 39–64 (2002)
16. Van Merriënboer, J.J.G., Kester, L.: Whole-task models in education. In: Spector, J.M., Merrill, M.D., Van Merriënboer, J.J.G., Driscoll, M.P. (eds.) Handbook of Research on Educational Communications and Technology, pp. 441–456. Lawrence Erlbaum, New York (2008)
17. Jesson, J.K., Matheson, L., Lacey, F.M.: Doing your Literature Review: Traditional and Systematic Techniques. SAGE, London (2011)
18. Van Merriënboer, J.J.G., Krammer, H.P.M.: The "completion strategy" in programming instruction: theoretical and empirical support. In: Dijkstra, S., Van Hout-Wolters, B.H.M., Van der Sijde, P.C. (eds.) Research on Instruction: Design and Effects, pp. 45–61. Educational Technology Publications, Englewood Cliffs (1990)

19. Sweller, J., Ayres, P., Kalyuga, S.: The guidance fading effect. In: Spector, J.M., LaJoie, S. (eds.) Cognitive Load Theory, vol. 1, pp. 171–182. Springer, New York (2011)
20. Brand-Gruwel, S., Wopereis, I.: Word Informatievaardig: Digitale Informatie Selecteren, Beoordelen en Verwerken (2e Herziene Druk) [Become Information Literate: Selecting, Evaluating, and Processing Digital Information; Revised Edition]. Noordhoff, Groningen (2014)
21. American Psychological Association: Publication Manual of the American Psychological Association, 6th edn. APA, Washington, DC (2010)
22. Hermans, H., Kalz, M., Koper, R.: Toward a learner-centered system for adult learning. Campus-Wide Inf. Syst. **31**, 2–13 (2014)
23. Westera, W., Wouters, P., Ebrecht, D., Vos, M., Boon, J.: Dynamic probing of educational quality: the SEIN system. In: Landeta, A. (ed.) Good Practice eLearning Book, pp. 165–176. ANCED, Madrid (2007)
24. Hattie, J., Timperley, H.: The power of feedback. Rev. Educ. Res. **77**, 81–122 (2007)
25. McKenney, S., Reeves, T.: Conducting Educational Design Research. Routledge, London (2012)