10 Information Problem Solving: Analysis of a Complex Cognitive Skill

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Abstract

In (higher) education students are often faced with information problems: tasks or assignments which require the student to identify information needs, locate corresponding information sources, extract and organize relevant information from each source, and synthesize information from a variety of sources. It is often assumed that students master this complex cognitive skill all by themselves. In our point of view, however, explicit and intensive education is required. In order to design education that fosters the information problem solving skill, a skill decomposition is required. In this research the complex cognitive skill of information problem solving is analysed. Experts and novices were observed while solving an information problem. Preliminary results reveal that experts spend more time on the sub-skills 'defining the problem', 'processing the information' and 'presenting the information'. They also regulate their process more often.

Keywords: Information problem solving, regulation, expert-novice analysis.

1. Introduction

Our current society is transforming into an information society. Both social and technological developments have contributed to a situation where information plays a key role (see Boekhorst, 2000). According to Marchionini (1999) the proliferation of electronic information technologies for computation and communication has speeded up the transformation process.

New technologies provide promising opportunities for accessing, storing, and distributing expanding amounts of information. However, these new technologies do indirectly create some problems. More than ever before people in our society are required to manage information overload, multi-tasking stresses, privacy and security issues, disorientation, distraction and addiction. Being able to adequately deal with information and to handle problems like techno stress and datasmog means being information literate. Marchionini (1999, p. 18) defines information literacy as "the skills, concepts, attitudes, and experiences related to information access, understanding, evaluation, communication, application, creation and value". An important component of information literacy is the ability to solve information problems, that is: to identify information needs, to locate corresponding information sources, to extract and organise relevant information from each source, and to synthesize information from a variety of sources into cogent, productive uses (Moore, 1995). In our study these activities are conceived as parts of one complex cognitive skill. This skill, which we refer to as information problem solving (see Eisenberg & Berkowitz, 1990, 1992; Moore, 1995), is complex, because it takes considerable time to achieve an adequate level of competence (cf. van Merriënboer, 1997). In contemporary higher education –due to a shift towards a learning-focused paradigm in instructional theory (see Reigeluth, 1999)- new curricula emerge that often appeal to information problem-solving skills. Examples are environments for resource-based learning (Hill & Hannafin, 2001; Macdonald, Heap & Mason, 2001), problem-based learning (Savery & Duffy, 1995), project-based learning (Land & Greene, 2000), and competence-based learning (Kirschner, Valcke & Van Vilsteren, 1997).

Since the skill of information problem solving is important in education and the skill requires substantial training, attention should be paid to the design of effective instruction. Before instruction can be designed, we need to analyse the skill. For a skills analysis, various methods can be used. The present study has chosen a comparison between novices and advanced information problem solvers. By choosing this approach two results were attained: (1) a decomposition and further analysis of the complex cognitive skill, and (2) an insight into the critical (sub) skills that distinguish advanced problem solvers from novices. Based on these results instruction can be designed.

Prior to the study, based on a review of literature, a preliminary model or framework of the information problem-solving skill was set up. The framework was derived from different studies. In the last decades the process of solving an information problem has been extensively studied and this has resulted in a variety of models (see for instance Spitzer, Eisenberg & Lowe, 1998, Wilson, 1999). According to Boekhorst (2000) most of these models can be characterized as information process models, which describe the steps one should undertake to fulfil an information need. Unfortunately higher-order thinking, like real problem solving and metacognitive activities, is underexposed in these process models (Boekhorst, 2000, McKenzie, 1994). Therefore, this first attempt to describe the process of information problem solving has explicitly paid attention to metacognition by distinguishing regulation as an important component of a new model. The preliminary model or framework, taken as the study's starting point, consisted of the following components:

Problem definition. During the first phase of the process of information problem solving the need for information is formulated and the required types and amounts of information are considered. The final goal of this phase is to get a clear idea of the problem and the information required for solving it.

Select sources. Once the information problem is formulated, the sources for solving it must be considered. In this phase sources are to be selected and prioritised, resulting in the formulation of a search strategy.

Search and find. During this phase the search strategy developed is actually followed. This strategy facilitates the search for the required information. The sources selected earlier are to be looked for and, once found, the information within has to be located. After scanning the information, the resulting requirement for additional information can be established. Boekhorst (2000) emphasizes that, in order to be successful in this phase, knowledge about information and communication technology is essential.

Processing. Once the required information has been located, the phase of information processing starts. During this phase it is important to examine the relevance of the information in relation to the problem. The information has to be studied and new ideas and concepts have to be integrated into prior knowledge. Activating prior knowledge during information processing may result in a deeper understanding (Dochy, 1993). Other activities that can be undertaken during this phase are: analysing, selecting, relating, and structuring information and critical thinking.

Organization and presentation. Once all the information required for solving the information problem is present, the information has to be organized and presented in such a way that the questions formulated in the first phase are addressed. Usually, a product has to be completed, for instance an essay or a presentation.

Evaluation. During this phase the product and the process are evaluated to ensure that the product is in line with the original question or task and that the problem-solving process is efficient. This is a kind of self-evaluation. It is important to retrace what went wrong and what turned out to be a good way of working, so that the approach and strategy used can be improved and fine-tuned according to one's own requirements and preferences.

Regulation. Regulation is not a phase. The regulation activities, which can be performed while solving the information problem, coordinate the entire process. Regulation activities can be described as: planning, diagnosing, monitoring and steering (Vermunt, 1995). The learner must be able to make a plan and check during the process if the plan should be adjusted, because of inefficiency and ineffectiveness. Good regulation is also a characteristic of a 'goal-directed approach" (Land & Greene, 2000). The interaction with the information is related to a preconceived plan. When using a 'data-driven approach' broad subject areas are identified, searches are conducted and information is read in order to formulate the goals, hypothesis or questions. So, there is not really a preconceived plan.

Research of Hill (1999), Hill and Hannafin (1997), Land and Greene (2000) and Marchionini (1995) has revealed that the quality of regulation is related to the effectiveness and efficiency of the information problem solving process. There is also evidence that the use of metacognitive knowledge and skills during the process can compensate for a lack of subject matter knowledge (Moore, 1995; Land & Greene, 2000).

In different kinds of education students get more and more tasks and assignments, which can be characterised as information problems. Because solving information problems can be seen as a complex cognitive skill, it is necessary to train students in this skill. In order to design education that fosters information problem solving, it is necessary to make a skill decomposition (Van Merriënboer, 1997). In this research the complex cognitive skill of information problem solving is analysed. Experts and novices have been observed while solving an information problem.

The aim of this study has been to come to a decomposition of the complex cognitive skill 'solving information problems'. Another goal of this study has been the comparison between experts and novices. To what extent does the information problem solving process of the experts differ from the process of the novices on 1) time investment in the main component skills, 2) use of regulation activities and 3) search patterns.

Guidelines for the development of education fostering the skill of information problem solving can be generated from the characteristics of and the differences between the experts and the novices.

2. Method

Participants

Five experts and five novices voluntarily participated in the study. The experts were PhD-students from the Open University of the Netherlands in their final years (two female, three male). The five novices were freshmen from a Dutch university studying Psychology.

Materials

Task. The participants were asked to solve an information problem while thinking aloud. The task description was: 'How must we deal with the perishability of food? Can we consume food that is out of date? Or must we rely on our senses? Write (in Microsoft Word) an argument of about 400 words, which is meant for a consumers' magazine. You can use information from the Internet to build up your argumentation.' The topic perishability was chosen because we expected that the prior knowledge on this would not differ too much between the participants.

Instrument to analyse the thinking aloud protocols. An inductive – deductive method was used to develop the coding system for analysing the thinking aloud protocols. The coding system was based on the framework described in the introduction and the protocols, and was tested and re-adjusted in a few iterations. Three kind of codes were used: descriptive, interpretative, and patterns (Miles and Huberman, 1994). Descriptive codes entail little interpretation and can be attributed to segments of the text in a straightforward way. Interpretative codes require more interpretation by the rater. Pattern codes are even more inferential and explanatory. They signal themes that account ".. for a lot of other data, make them intelligible, and function like a statistical 'factor', grouping disparate pieces into a more inclusive and meaningful whole" (Miles & Huberman, 1994, pg. 58). Furthermore, the system consisted of three types of categories, organised in three columns that were scored simultaneously. In the first column, the six main skills (or phases) of information problem solving were scored in an exclusive and exhaustive way. The six categories were: define the problem, search for information, scan for information, process the information, organize and present the information and evaluate the process and product. In the second column the categories representing the sub-skills were scored. Each main skill (or phase) was refined by several sub-skills that could only be scored during the main phase. For instance: the category 'defining the problem' consisted of: reading the task, explaining the problem, activating prior knowledge, determining the prerequisites, making notes. In the third column categories on the following topics were scored: regulation of the process, regulation of emotions, interventions and remarks of the session leader, and several pre-defined pattern codes. These categories could be scored independently of the scoring in both other columns. Regulation included: monitoring and steering of one's working process, orientation on the process, and testing of the results during the process. The first two pattern codes were related to the moment of deciding that the information was sufficient for completing the task. The first pattern indicated that a participant searched a lot of information first and decided *later on* that sufficient information had been found. The second pattern indicated that *after a short period* of searching, the student decided that sufficient information had been found. The next three pattern codes concerned the way people search the Internet. There were three possibilities: (a) *meandering:* starting from a list with results and surfing from site to site using hyperlinks; (b) *browsing subject categories/databases*: starting a search from a structured site and finding the information needed through refining; (c) *list link*: going to a site by a result overview of a content based search (search engine), returning to that overview and going to a new site, etc. The next three pattern codes were related to the search strategy used. Again there were three possibilities: (a) a *goal-oriented approach:* participants seek information in the context of a goal, hypothesis or question; (b) a *data-oriented approach:* participants identify broad subject areas, conduct a search and read information on a topic and formulate the goals, hypothesis or questions from the resources; (c) a *chaotic approach*, participants are lost and do not know where to search.

Design and Procedure

The participants were asked to come to the Multi-Media-Laboratory of the Open University of the Netherlands. At the beginning of each individual session the participant was instructed on the purpose and procedure of the session, and on what thinking aloud involved. They also read the task and could ask questions on the task (10 minutes). Once the session leader had left the room the participant had one and a half hours to complete the task. During this time the participant could use Internet to search for information and Microsoft Word to present the information. During the session the computer actions and the thinking aloud expressions of the participant were recorded on digital video. All Internet actions were logged on the computer. The session leader watched the participant through a one-way screen and could communicate with the participant by microphone. He or she mainly encouraged the participant to keep on thinking aloud and answered questions if there were any. All tapes were typed-out into protocols.

Data-analyses

Two trained raters scored the protocols and the video-registrations by using the coding system. In the first round four of the ten protocols were scored. The interrater reliability was calculated for these four protocols and the raters reached consensus on the statements they disagreed on. Next, the raters scored another two protocols in the second round. Again interrater reliability was calculated and consensus was reached. Only one rater scored the remaining four protocols. Table 1 gives an overview of the interrater reliability on the main skills and the regulation variables. Sub-skills variables have not been included, as these have not yet been analysed.

	Main skills		Regulation	
	P_a	Kappa	P_a	Kappa
First round	.72	.67	.35	.13
Second round	.76	.72	.54	.39

Pa = Percentage of agreement

Table 1. Interrater reliability on the main skills and on regulation

3 Results

The first question concerned the decomposition of the information problem solving skill. During the development of the coding-system and while analysing the protocols the (sub)skills emerged. Figure 1 gives an overview of the important (sub)skills.

	Analysis				Synthesis	
	define problem	**search information**	**scan information**	**process information**	**present information** (write)	**evaluate**
	concretize problem	internet skills - search strategies			formulate problem	process-evaluation
	activate prior knowledge	derive search terms	scan site (skimming)	read	outline product	product-evaluation
	prerequisites product	judge search results	judge scanned information	deep process of information	structure the product	
			think about the content	judge processed information	formulate text	
					think about content	
remaining	Regulation (monitoring / steering, orientation on task and time, test on content, etc.)					

Figure 1: Skill decomposition of the information problem solving skill

The next question concerned the extent to which novices and experts differed while using the (sub)skills. Figure 2 shows the time investment in the main component skills by the novices and the experts. The time investment in this figure is calculated as the time spent on the main component skills divided by the total time spent on the task.

The novices and the experts differed in the main skills: defining the problem, processing the information and presenting the information (writing the text). The data revealed that none of the participants evaluated the process or the product after completion of the task.

Another difference between the experts and the novices was the time they spent on completing the task. The average time spent by the experts was 91,7 minutes (*SD*=6,46). The average time spent by the novices was 71,6 minutes (*SD*=20,06).

Because the experts were expected to show more self-control in their information problem solving processes, the differences between the two groups on the regulation variables were calculated. The frequencies of all regulation variables were calculated and divided by the time on task.

Table 2 gives the frequencies of the regulation variables and the frequencies divided by the time of task per participant. Figure 3 shows the mean differences on regulation between the experts and the novices.

Finally the differences between the experts and the novices on search patterns were analysed. Figure 4, 5 and 6 give an overview of these.

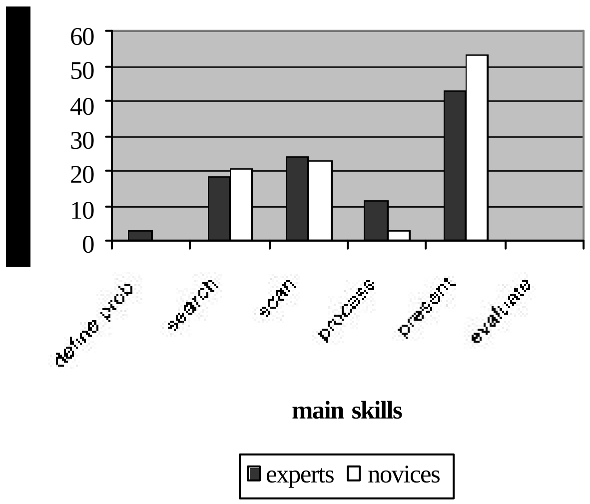

Figure 2. Differences in main skills between expert and novices in percentage of time

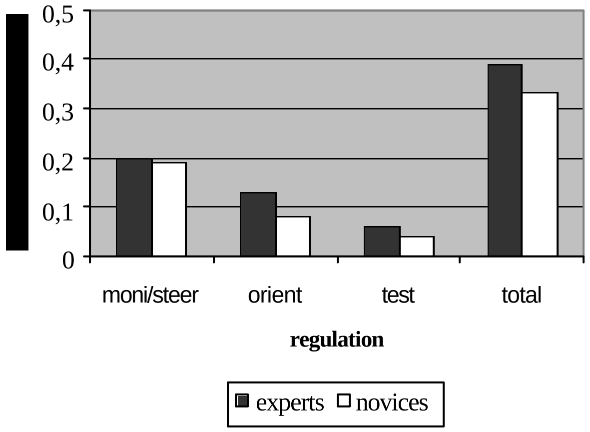

Figure 3. Differences between novices and expert on regulation

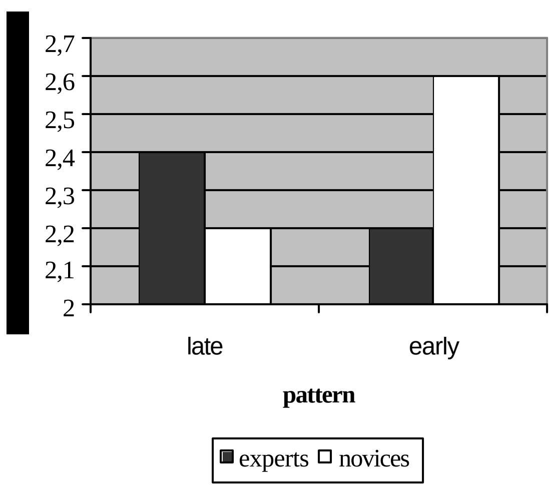

Figure 4. Moment of decision if information is sufficient

	Time on task	10.1.1.1	Frequencies Regulation		
	minutes	**moni-steer**	**orien**	**test**	**total**
Expert 1	95,5	12	9	2	23
Expert 2	91	27	13	7	47
Expert 3	83	15	6	8	29
Expert 4	89	12	9	5	26
Expert 5	100	26	21	6	53
Total Exp.	458,5	92	58	28	178
Novice 1	88	17	10	9	36
Novice 2	40	1	4	2	7
Novice 3	70	5	4	0	9
Novice 4	70	20	3	1	24
Novice 5	90	24	8	4	36
Total Nov.	358	67	29	16	112

	Time on task	**10.1.1.1.1**	**Frequencies Regulatio Time on Task**		
	minutes	**moni-steer**	**orient**	**test**	**total**
Expert 1	95,5	0,13	0,09	0,02	0,24
Expert 2	91	0,30	0,14	0,08	0,52
Expert 3	83	0,18	0,07	0,10	0,35
Expert 4	89	0,14	0,10	0,06	0,29
Expert 5	100	0,26	0,21	0,06	0,53
Total Exp.	458,5	M. 0,20	M. 0,13	M. 0,06	M. 0,39
Novice 1	88	0,19	0,11	0,01	0,41
Novice 2	40	0,03	0,01	0,05	0,18
Novice 3	70	0,07	0,06	0,00	0,13
Novice 4	70	0,29	0,04	0,01	0,34
Novice 5	90	0,27	0,09	0,04	0,40
Total Nov.	358	M. 0,19	M. 0,08	M. 0,04	M. 0,31

Table 2. The frequencies of the regulation variables and the frequencies divided by the time of task per participant

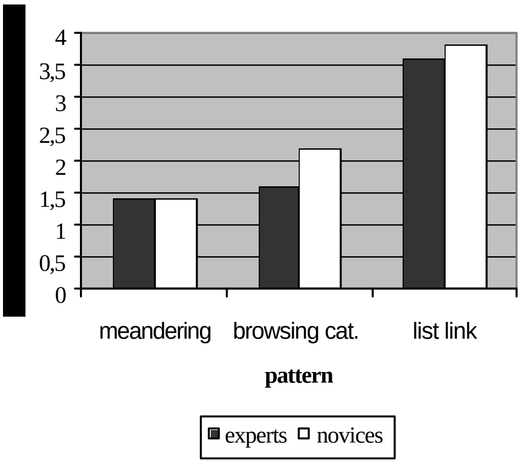

Figure 5. Way of searching the Internet

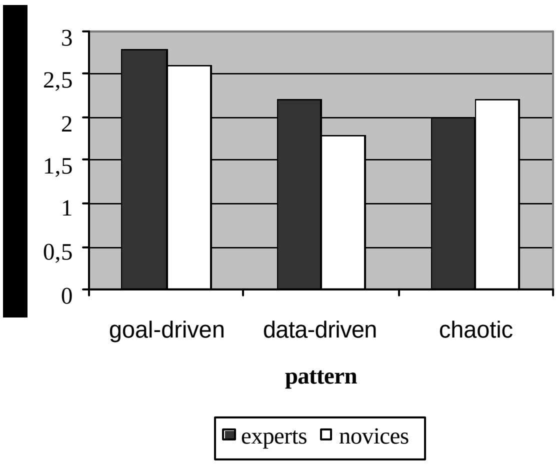

Figure 6. Used search strategy

Figure 3 shows that in general the experts regulated there process more often. It appears that the experts in general decided at a later stage which information was useful for completing the task (Figure 4), while the novices decided earlier on in the process which information would be used, and, consequently, started their writing-process earlier. The way experts and novices searched the Internet hardly differed: both groups mainly searched by using the list-link approach (Figure 5). Nor was there a marked difference in the search strategies used: as both mainly used the goal-driven approach. It is, however, striking how often the 'chaotic' strategy occurred.

4. Conclusion and discussion

The aim of this study was to come to a decomposition of the complex cognitive skill information problem solving by observing experts and novices while completing an information problem solving task. Another goal of this study was the comparison of experts to novices. Differences with respect to 1) time investment in the main component skills, 2) use of regulation activities and 3) the patterns concerning the moment of deciding if information is sufficient, the way the Internet is searched and the search strategies used.

From the theory and the data a skill decomposition was constructed which was largely compatible with the framework presented in the introduction. The categories 'select sources' and 'search and find' in the framework and the skills 'searching for information' and 'scanning information' differed, however. Searching for information included in our view the decision on which search-strategy was to be used, the process of searching itself, up to the judgement of the sources found. The stage of scanning the information started when a person skimmed the information in a source. In the original framework those stages were more interwoven.

The comparison between the experts and the novices has revealed that there are some differences between the two groups. Novices spend less time on defining the problem in the beginning of the process. Experts probably asked themselves more often: 'which information do I need to accomplish the task? What do I already know and what kind of information must I search for? The retrospective interviews, which were held after the participants accomplished the task – but which have not been analysed as yet – may provide more information on this.

In general the participants did not spend much time on processing the found information in depth. However, the experts took more time to study and process the information in a deeper way.

In general the participants invested a lot of time in organizing and presenting the information, c.q. in writing the argumentation. According to the skill decomposition this part of the process is the synthesis. Compared to the experts the novices spent more time on writing. This result is in line with the results on the patterns, which showed that novices generated less information and decided at an early stage whether the information was sufficient.

Neither the experts nor the novices evaluated the process and the product after completing the task. The fact that the participants skipped this part of the process may be due to the characteristics of the task. The task was not very complex, therefore, the participants may well have been able to form a clear picture of the quality of their product during completion of the task.

Experts regulated their information problem solving process more often than the novices. They showed more expression of monitoring and steering activities during the task performance, they oriented themselves more often on for example the task and tested the results more frequently during the process. It will be investigated in the near future whether this also resulted in better products. If this is indeed the case, this result will be in line with research of Hill (1999); Hill & Hannafin (1997), Land and Greene (2000), and Marchionini (1995). They found that students who regulated their information problem solving process more often were more effective and efficient in their way of working.

As shown by the results on the pattern codes, a difference was found with respect to the moment of deciding whether the information was sufficient. The experts decided at a later stage which information was sufficient for accomplishing the task while the novices decided this earlier on in the process. It is assumed that experts do have another conception of a task and probably set higher demands, which may well lead to a longer period of searching, because they are not satisfied until they have reached their goals. This may also be an explanation for the fact that the experts spent more time on completing the task.

The way experts and novices searched the Internet was the same. They all used the list-link approach most of the time. Neither did they differ in their use of the goal-driven, data-driven or chaotic approach. However, we did notice that on the whole the chaotic approach occurred more often than expected. The fact that no differences were found between the data- and goal-driven approaches may again be due to the characteristics of the task, which was quite open. For example, there were no restrictions on the content of the argument. Therefore, a combination of the data- and goal driven approach could be considered to be an appropriate approach for completing the task. While searching the Internet participants came up with interesting information and decided to use this information in their argumentation. This is in line with the data-driven approach. But participants also often used the information found for adjusting their preconceived plan.

The study described in this paper is part of a larger research. The following research questions will be addressed in the near feature. What do the information problem solving processes look like in depth? Once the analyses of the sub-categories of the main skills have been finalised we hope to gain a better insight into the use of the sub-skills. Another question is the relation between the way participants solved information problems and the quality of the arguments written. Are the expert argumentations of a better quality? Finally we will discuss the heuristic knowledge of the participants. This will be done by another close examination of to the protocols and particularly the retrospective interviews, which were conducted following completion of the tasks. Again the differences between the experts and the novices will be analysed.

After finalisation of the entire research guidelines for implementing instruction on information problem solving will be generated.

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