Computers & Education 53 (2009) 1207–1217

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

A descriptive model of information problem solving while using internet

Saskia Brand-Gruwel *, Iwan Wopereis, Amber Walraven

Open University of the Netherlands, Centre for Learning Sciences and Technologies, P.O. Box 2960, 6401 DL Heerlen, The Netherlands

ARTICLE INFO

Article history:
Received 20 March 2008
Received in revised form 4 June 2009
Accepted 5 June 2009

Keywords:
Media in education
Learning strategies
Lifelong learning

ABSTRACT

This paper presents the IPS-I-model: a model that describes the process of information problem solving (IPS) in which the Internet (I) is used to search information. The IPS-I-model is based on three studies, in which students in secondary and (post) higher education were asked to solve information problems, while thinking aloud. In-depth analyses of the thinking-aloud protocols revealed that the IPS-process consists of five constituent skills: (a) defining information problem, (b) searching information, (c) scanning information, (d) processing information, and (e) organizing and presenting information. Further, the studies revealed that regulation skills prove to be crucial for the on-going IPS-process. The IPS-I-model depicts the constituent skills, regulation skills, and important conditional skills. The model gives an initial impetus for designing IPS-instruction.

1. Introduction

In contemporary education, emphasis is on meaningful learning, knowledge construction and self-directed learning (Kicken, Brand-Gruwel, & Van Merriënboer, 2008; Loyens, Magda, & Rikers, 2008). To stimulate students to construct knowledge in a meaningful way, students receive learning tasks and assignments that require them to identify information needs, locate information sources, extract and organize information from each source, and synthesize information from a variety of sources. This set of activities is frequently defined as information problem solving (IPS)[1] (Brand-Gruwel, Wopereis, & Vermetten, 2005; Eisenberg & Berkowitz, 1990; Moore, 1995; Wolf, Brush, & Saye, 2003). IPS is a concept that combines the skills needed to access and use information, whether or not found on the World Wide Web (WWW). In other words, an information-based problem is a problem for which information is required to solve it.

Research shows that many students are not able to solve information-based problems successfully. Research of Bilal (2000), Large and Beheshti (2000), MaKinster, Beghetto, and Plucker (2002), Wallace, Kupperman, Krajcik, and Soloway (2000), for instance, reveals that young children, teenagers, and adults do not always know which search terms to use when searching the WWW for information. Moreover, people of all ages do not always open websites based on a valid judgement of the results. The source is not always questioned and the choice to open a site is highly guided by the title or summary of the site. Furthermore, research of Brand-Gruwel et al. (2005), Branch (2001), and Lazonder (2000) reveals that students lack regulatory skills and have difficulties defining the problem. Taking these research results into account, it can be concluded that students must learn to solve information-based problems and must learn transferable strategies.

Guidelines to design IPS-instruction are therefore needed. The decomposition of the IPS-skill is a first step in designing IPS-instruction and the formulation of instructional design guidelines. Because the IPS skill can be characterised as a complex cognitive skill, the designer of instruction must be aware of the nature of skill acquisition, the heterogeneity of the constituent skills involved, and the underlying learning processes. This means it is essential to unravel the mental models representing the knowledge underlying the performance of the skill and the cognitive strategies involved when completing tasks. A decomposition provides an overview of the cognitive strategies and mental models involved. Insights in the cognitive processes are the input for developing a systematic problem approach. Furthermore, insight in the cognitive strategies and skills are input in defining the mental models needed to carry out the skills (van Merriënboer, 1997). The aim of this paper is to present the skills involved in: the IPS-I-model. This model describes the main skills, regulation skills, and most relevant conditional skills needed to solve information problems.

Before going into the model, the method used and the results in order to verify the model, research on IPS will be discussed. Already defined models will be addressed and the added value of the new model to the already existing models will be emphasised.

* Corresponding author. Tel.: +31 45 5762148.
E-mail address: saskia.brand-gruwel@ou.nl (S. Brand-Gruwel).

[1] Information-problem solving is the term we use in our research. Information seeking can be regarded as a synonym for IPS.

0360-1315/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compedu.2009.06.004

Up to now research on the IPS-process has resulted in a large body of knowledge. Many researchers in library, information, and educational sciences have examined behaviours and skills associated with information use (see, e.g., Brand-Gruwel et al., 2005; Hill, 1999; Hölscher & Strube, 2000; Kuhlthau, 1993; Lazonder, Biemans, & Wopereis, 2000; Marchionini, 1999; Oliver & Perzylo, 1994; Stripling & Pitts, 1988; Sutcliffe & Ennis, 1998; Yang, 1997; Zins, 2000). Considering this research three prominent models are: (a) the search process model (Kuhlthau, 1993), (b) the research process model (Stripling & Pitts, 1988), and (c) the Big6-model (Eisenberg & Berkowitz, 1990).

Kuhlthau (1993) describes the process of IPS in seven stages (initiation, topic selection, exploration, formulation, collection, presentation, and assessment), by examining the thoughts, feelings, and actions associated with various activities within this complex process. However, in a revised edition of her aforecited book, Kuhlthau (2004) describes six stages instead of seven. The presentation stage is now called 'search closure', and the assessment stage is, for certain elements, incorporated in this closure stage. The model, based on examinations of searchers in a variety of situations, depicts the changes searchers experience when going through a process from a more fuzzy and unfocused state of mind to a focused one, while searching relevant, suitable, and reliable information. The transition from one stage to another is often accompanied by positive or negative feelings: negative emotions such as uncertainty, confusion, frustration, and positive emotions such as optimism, clarity, confidence, and relief.

Stripling and Pitts (1988) describe their search-process model as a 'thinking frame' for research. This ten-step process emphasises a thinking framework that can be adapted to any age level and any curricular subject. The steps are: choosing a broad topic, getting an overview, narrowing down the topic, developing the statement, formulating questions, planning research, finding – analysing and evaluating – information, evaluating evidence, establishing conclusions, and creating and presenting a product. The model can be seen as a method for writing research papers and is organized around the major activities performed in writing a coherent research paper. During the process, students have several reflection points that allow them to make judgments about their progress.

Kuhlthau (1993) and Stripling and Pitts (1988) examined the search process from the point of view of the searcher. Eisenberg and Berkowitz (1990) formulated a model that can be used both by students (searchers; to guide their thinking and research activities), and teachers (to guide their planning and implementation of classroom instructional activities). Their Big6-model is a six-step process that provides support in the activities required to solve information problems: task definition, information seeking strategies, location and access, use of information, synthesis, and evaluation. The model has proven to be a successful (Eisenberg, 2006) and effective (Wolf et al., 2003) prescriptive educational model.

The three models described have much in common. For instance, all models describe a certain flow through the whole IPS-process. They all start with the stage in which the tasks must be set. However, there are also differences between the models which can be related to the various situations the IPS-process is examined in. The model of Stripling and Pitts (1988) focuses on writing research papers and stresses the research process, while the models of Kuhlthau (1993) and Eisenberg and Berkowitz (1990) are based on various situations in which information-based problems must be solved. Furthermore, Kuhlthau (1993) stresses the importance of feelings when solving information problems. Feelings are important because they are also related to regulation activities. A feeling of frustration caused by the fact that you cannot find the right information, can lead to regulation activities like steering or defining a new search strategy. Finally, the model of Eisenberg and Berkowitz (1990) did not only focus on the students' IPS-process, but was especially formulated to help teachers to design their education to foster students' IPS-ability.

To answer the question whether it is necessary to formulate a new model for Information problem solving, we will address the impact the World Wide Web has on the IPS-process, and the need for more regulation of this process.

The three prominent models (Eisenberg & Berkowitz, 1990; Kuhlthau, 1993; Stripling & Pitts, 1988) are more than 10 years old and are *not* primarily based on situations in which students use the WWW to search information. Since the arrival of the World Wide Web the IPS-process has changed. Searching the Web for information differs from searching a library database or a table of contents. The web does have its own structures, the amount of information is enormous, and there are no gatekeepers that filter information. The enormous amount and the organization of the information available on the WWW, and the fact that finding the right information becomes a more rapid action, makes it that certain aspects of the process become more prominent. These aspects will be addressed in the IPS-I-model.

2. The IPS-I-model

From literature concerning processes and skills involved in solving information problems while using the internet (Brand-Gruwel et al., 2005; Eisenberg & Berkowitz, 1990) insight is gained in the constituent skills and sub skills. This insight formed the foundation for the presented model. First, this model will be described. Second, the combined results of three datasets are presented to verify the mode. Furthermore, information will be given about how the IPS-process differs on certain aspects between the different groups of students. These differences can be regarded as input to the design of IPS-instruction.

The model describes the skills needed to solve an information problem when the internet is used to search information. Fig. 1 presents this model. The five constituent skills, namely 'Define information problem', 'Search information', 'Scan information', 'Process information', and 'Organize and present information' are linked blocks. Regulation happens during the execution of all skills and is visualized by the arrows. The five blocks rest upon three layers which represent the three most important conditional skills: (a) 'Reading skills', (b) 'Evaluating skills', and (c) 'Computer skills'.

2.1. The five constituent skills

The constituent skill *Define information problem* will always be performed at the beginning of the process. This skill is important in order to get a clear insight into the problem (e.g., Hill, 1999; Land & Greene, 2000; Moore, 1995). Without a good problem definition, the problem becomes hard to solve and answers may not be adequate. While defining the problem, the main question and sub questions are formulated, requirements are taken into account, and prior knowledge on the subject matter must be activated.

When performing the skill *Search information*, one has to select a search strategy, specify search terms, and judge the websites given in a hitlist. There are several search strategies that can be used while searching information on the WWW. The three most commonly used strategies are (a) using a search engine, (b) typing an address (URL) in the browser and (c) browsing by following links (Lazonder,

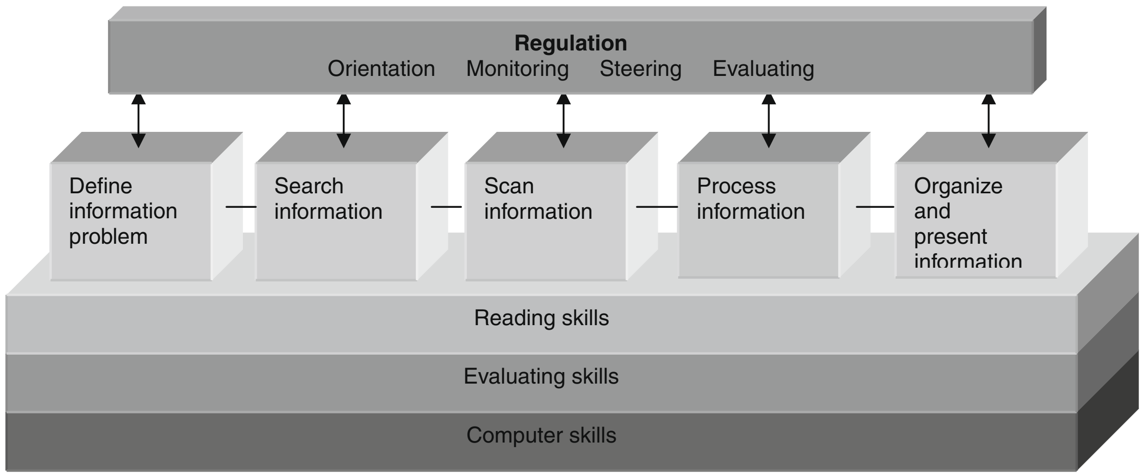

Fig. 1. The information problem solving using internet model (IPS-I-model).

2000). When using the first strategy, an important sub-skill is specifying the search term(s). This term is entered in a search engine (e.g., Google™). This engine then returns a list of results (the 'hitlist') of titles and short summaries of possible relevant sources (e.g., websites or pdf-files). These results have to be judged on quality, relevance, and reliability (Wopereis, Brand-Gruwel, & Vermetten, 2008).

When the search process is 'goal-driven' and the problem is clearly defined, the search terms used will be more detailed and specific. The specificity of used terms depends also on students' prior knowledge. The more knowledge students have about the subject matter, the easier it is to define the search terms and to refine them if necessary. When the process is more 'data-driven', and the problem is not well-defined, the search strategy will be broader defined.

The site that is opened after a search will be scanned (*Scan information*) to get an idea of the kind of information, and whether it is useful. While scanning one can elaborate on the content and combine the information with previous knowledge or other information found. When information is useful, it can be stored by using bookmarks or by copying and pasting information in a Word-file.

As opposed to scan information, the constituent skill *Process information* involves deep processing. The goal is to reach a deep understanding of the information (Schmeck & Geisler-Brenstein, 1989), and to reach an integration of the different pieces of information found with relevant prior knowledge (Wopereis et al., 2008). Elaboration is an important part of the constituent skill and can be expressed by analysing, selecting, and structuring information. Especially for selecting information, criteria for judging the usefulness and quality of information are important.

The first four skills are part of the analysis phase. *Organize and present information* is part of the process that can be described as the synthesis. All the information will be combined and the information problem can be solved. Making the product as required in the task is the goal or outcome of this constituent skill. Several products are possible: a presentation or a poster, or a written product like an essay. For every product, the problem must be formulated, since this is the basis of the product. The layout must be determined and the components defined in this outline must be further structured and filled in. During this organizing and presenting of information elaboration remains important (Wopereis et al., 2008).

2.2. Regulation activities

As can be seen in Fig. 1, *Regulation* activities will be carried out during the entire IPS-process. Especially because the WWW is such an extensive source of information, a strong appeal to peoples' regulation ability is made. Regulatory aspects such as orientation, monitoring, steering, and evaluation, play a key role in the execution of the skill (Brand-Gruwel et al., 2005; Hill, 1999). The students need to make a plan for how to solve the information problem. During the process they have to monitor, steer, and check whether the proposed plan is still the right one, or decide if changes in the approach are needed. When a process is regulated well, it will resemble a 'goal-directed approach' (Land & Greene, 2000). In this approach the interaction with the information will be guided through an overall plan, while in the 'data-driven approach' a plan (mostly incoherent) develops. The efficiency and effectivity of the process correlate with the quality of the regulation activities (Hill, 1999; Hill & Hannafin, 1997; Land & Greene, 2000; Marchionini, 1995; Tu, Shih, & Tsai, 2008). Moreover, the efficient use of regulation activities can compensate for a lack of domain knowledge (Land & Greene, 2000; Moore, 1995).

Thus, the IPS-process can be divided into five constituent skills and regulation activities. These skills and activities must be performed at an adequate level to solve information problems successfully. However, to do so three underlying skills can be distinguished from our data. These 'reading skills', 'judging skills', and 'computer skills' can be characterised as conditional.

2.3. Conditional skills

During the performance of an IPS-task and the search for information on the internet, students' *reading ability* is important. As also addressed by resent researchers (Coiro, 2003; Leu, Kinzer, Coiro, & Cammack, 2004) reading hypertext differs from reading printed material. Hypertext can be defined broadly as a collection of documents containing links that allow readers to move from one chunk of text to another. Hypertext makes reading interactive and enables readers to develop rich, highly interconnected knowledge structures (Fiderio, 1988; Fredin, 1997; Jacobson & Spiro, 1995; Spiro & Jehng, 1990). However, the flexibility and interactivity proposed as advantages of hypertext result in a complex reading comprehension process. Users can choose their own reading path, far more than in printed materials, by following links. Besides, the reader is guided through the links the author of the website created. The reader must be able to process and organize the bits of information read and create an own structure. Knowledge of how websites are structured and knowing the possibilities for navigation facilitate the reading process, and can prevent the 'disorientation problem' (Rouet & Levonen, 1996). To make reading a hypertext successful, reading comprehension strategies are important such as checking difficult words, asking oneself questions concerning the content, summarizing, making use of non-textual information to construct meaning, making inferences, etc. (see also Brand-Gruwel, Aarnoutse, & Van den Bos, 1998). Moreover, in our data (i.e., thinking aloud protocols) we found those aspects to be important. Students read text globally while scanning and studying text in more depth when processing information and also elaborate on the content during the process, to construct knowledge and to grasp the meaning.

Due to the fact that everyone can put information on the WWW it is of major importance that students are able to *evaluate* the information and the sources found. The Web is easily accessible and students are seduced to cut and paste the information without evaluating it (Grimes & Boening, 2001; Rothenberg, 1998), resulting in reports that lack quality.

Research has shown that evaluating and selecting sources and information when solving an information problem is a problem for students of every age (Duijkers, Gulikers-Dinjens, & Boshuizen, 2001; Fidel, Davies, Douglass, Holder, Hopkins et al., 1999; Hirsch, 1999; Kafai & Bates, 1997; Koot & Hoveijn, 2005; Lorenzen, 2002; Lyons, Hoffman, Krajcik, & Soloway, 1997; MaKinster et al., 2002; Wallace et al., 2000).

Evaluating sources in a hitlist is mostly done based on titles and summaries provided by the search engine, the number of results and the order of results (Duijkers et al., 2001; Fidel et al., 1999; Hirsch, 1999; Kafai & Bates, 1997; Koot & Hoveijn, 2005; Lyons et al., 1997; Wallace et al., 2000; Walraven, Brand-Gruwel, & Boshuizen, 2009). Also students' prior knowledge influences the criteria used to evaluate sources in a hitlist. Students who have much prior knowledge evaluate results by title, origin, summary, and identifiers in the URL (.edu or .gov) (MaKinster et al., 2002).

Koot and Hoveijn (2005) argued that evaluating and selecting sources and information is not always done based on clear criteria, but on intuition. Young children tend to believe that everything on the Web is true (Hirsch, 1999; Schacter, Chung, & Dorr, 1998), especially when they find the same information on multiple sites (Koot & Hoveijn, 2005). Teenagers use information that can solve their information problem without thinking about the purpose of a site (Fidel et al., 1999). They also find it hard to express how they evaluate and select information (Lorenzen, 2002). It can be concluded that students hardly evaluate results, information and sources (Walraven, Brand-Gruwel, & Boshuizen, 2008).

C*omputer skills* are important while searching on the WWW. This involves, amongst others, typing skills and navigation skills (e.g., typing in a search term and following links). Marchionini (1995), and Sutcliffe and Ennis (1998) also confirm that computer skills are important during the IPS-process.

3. Research questions and hypotheses

This paper focuses on the IPS-process and the skills and regulation activities involved. The aim is to build a descriptive model depicting the process of information problem solving when using the internet (especially the WWW) to search information. In order to verify the model, the following questions are addressed: 'Do students perform all the constituent skills and regulation activities as described in the model when they solve information-based problems using internet to search and find information?' An additional question is: 'How do different kinds of students go through the process and hour do they differ in the performance of the constituent skills, regulation skills, and the condition skills 'reading' and 'evaluating?' This question is important because it can give input to the design of IPS-instruction for different kinds of students.

To answer the questions, data of three studies (Brand-Gruwel & Wopereis, 2006; Brand-Gruwel et al., 2005; Walraven et al., 2008) are combined. In these three datasets, data concerning four groups of students are gathered: (a) PhD-students in their final year, (b) freshmen in Psychology, (b) student teachers in their second or third year, and (d) 9th graders in secondary education (see Appendix A for an overview of these studies). Analysing the IPS processes of different kinds of students is important in order to determine whether the model depicts the important elements of IPS for a wider range of people. The fact that the data were gathered under different circumstances will be discussed in Section 4.

It is expected that all defined constituent skills will occur in all groups of students and that the process is iterative. From literature (Eisenberg & Berkowitz, 1990) it is known that the skills are not performed in a linear way. For instance, after scanning a website, a person can decide to go back to the search engine and search again, or to redefine the problem and main questions. Especially the results of the regulation activities are input for the process and making it iterative. However, differences are predicted in the use of the skills and the time investment in the skills between the four groups of students. It is assumed that children (secondary education) rarely take the time to read a site in-depth and spend much time processing information (Kafai & Bates, 1997; Schacter et al., 1998; Wallace et al., 2000). Furthermore, it is expected that these young students regulate their process less than the students in the other groups, because the latter are likely to be more experienced (Hirsch, 1999; Lazonder et al., 2000).

With regard to the conditional skills only research questions concerning reading and evaluating are formulated in the three studies. Computer skills are considered a control variable in the different studies, because it is known that students' computer experience does matter (see also, Tu et al., 2008). Students' knowledge of this matter was measured, but it was not measured in the same manner in the different studies. Although five point scales were used most of the time, the questions were different. Hence the one thing that became clear concerning this matter is that all students had more than average knowledge and perceived skills on how to use the computer and on how to search the WWW.

4. Method

4.1. Participants

Study 1: Five PhD-students and five freshmen in Psychology participated in the study voluntarily. The PhD-students (two female, three male; mean age 33.0, *SD* = 9.96) studied in the field of Educational Technology at the Open University of the Netherlands. They were all in their final year. The Psychology freshmen (four female, one male; mean age19.20, *SD* = 1.30) were students at a Dutch University.

Study 2: Fifteen students (14 female, 1 male; mean age 21.13, *SD* = 1.86) from a teacher training college for secondary Dutch language education (in their second or third year) participated in this study.

Study 3: Twenty-three students of two schools for secondary education participated in this study. All students (8 boys and 15 girls; mean age 14.22, *SD* = .422) were half way the 9th grade of pre-university education.

4.2. Tasks to measure the IPS-skill

The design of the tasks in the first two studies was almost identical: students were asked to solve an information problem about how to deal with food that is out of date. Because the task aimed to measure the IPS-skill, a neutral topic was chosen. The task description in both studies was: 'how to deal with the perishableness of food? Can we consume food that is out of date? Or must we rely on our senses? Write a concept article in Microsoft Word (study 1)/an outline for an article (study 2) of about 400 words, which is meant for a consumers' magazine. Use information from the internet to build your argumentation'. In the first study students had to produce a concept article in one and a half hour. In the second study students were asked to make an outline in 1 h.

To give an idea about the type of task used, we refer to the task complexity levels of Mosenthal (1998). One of the levels concerns the information needed. In this case the information needed can be regarded as evidence; evidence to show that we must take the description 'best before' on food seriously. Furthermore, Mosenthal distinguishes different kinds of tasks (locate task, cycle task, integrated task and generate task). The used task can be characterised as an integrated task. Different pieces of information (opinions) must be integrated to come to an answer.

The seven tasks used in the third study (four physics, three geographic) consisted of a question, which had to be answered with information found on the Web. Students had to formulate a short answer in a Word file. The questions were: (1) Ecological changes have become clearly visible during the last years. The snow line of the Kilimanjaro is moving and the ice of the polar caps is melting. Can all this be prevented if the Kyoto protocol is followed? (2) Under which circumstances does the road reflect like a mirror in the distance? (3) Why do the Netherlands have charcoal layers of 1–2 m thick, situated far below the surface while the USA has layers 40 m thick situated near the surface of the earth? (4) Why are hailstones sometimes small and sometimes big? (5) An electron has a charge, but what is this charge exactly? (6) What is the effect of pollution on the quality of tap water? (7) Why is there so much air in a snowflake? To ensure comparability of the tasks, constructs defining the difficulty levels of prose-task processing (Mosenthal, 1998) were controlled for. Like the task concerning perishableness of food, these tasks could be specified as integrated tasks. After the tasks were designed, a panel of four persons tested them. These persons were all educational scientist, and experts in IPS. They solved the problems and filled out a questionnaire after each task, concerning time on task, used keywords, used websites and difficulty level. No significant differences were found between the tasks.

4.3. Instrument to analyse the thinking aloud protocols

An inductive–deductive method was used to develop the coding system for analysing the thinking aloud protocols in the three studies. This means that the coding system was based on the protocols and the literature (Miles & Huberman, 1994), and was tested and re-adjusted in a few iterations. For scoring the protocols two kinds of codes were used: descriptive codes and interpretative codes. 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, for instance, scoring regulation activities. The scoring system itself consisted of three categories, which were scored simultaneously.

The first and second category pertained to the reformulated constituent skills and their sub-skills and they were scored in an exclusive and exhaustive way. This means that each constituent skill was refined into several sub-skills that could only be scored as sub-skill of the constituent skill. The skill 'define information problem' consisted of five sub-skills: (a) read task, (b) formulate questions, (c) activate prior knowledge, (d) clarify task requirements, and (e) determine needed information. The skill 'search information' contained three sub-skills: (a) select search strategy, (b) specify search terms, and (c) evaluate source in hitlist. The skill 'scan information' consisted of four sub-skills: (a) read information global, (b) evaluate information/source, (c) store relevant information, and (d) elaborate on content. The skill 'process information' consisted of three sub-skills: (a) read text in depth, (b) evaluate source and information, and (c) elaborate on content. The skill 'organize and present information' contained: (a) formulate problem, (b) structure relevant information, (c) outline the product, (d) realize the product, and (e) elaborate on content.

The third category consisted of the regulation activities. These activities could be scored independently of the scoring in both other categories. Regulation of the process included (a) monitoring and steering of one's own working process, (b) orientation on the process, and (c) evaluating the results during and after the process.

4.4. Design and procedure

In the Brand-Gruwel et al. (2005) study, five PhD-students and five Psychology freshman participated. The participants were asked to think aloud while solving the task about the perishability of food. Students got one and a half hour to accomplish the task. In the second study (Brand-Gruwel & Wopereis, 2006), as part of a lager experiment, 15 student teachers solved the same information problem in 1 h. In the third study, 23 secondary education students had an hour to finish two tasks (out of seven), again while thinking aloud.

At the beginning of each individual session, the experimenter informed the participant about the purpose and procedure of the session, and what thinking aloud involved. Then the participant read the task and was given the opportunity to ask questions about the task. After this introduction, the participant had one-and-a-half hour (study 1) or 1 h (study 2) or half an hour twice (study 3) to complete the tasks. During the session all computer actions, including internet use, and the thinking aloud expressions of the participant were recorded on digital video. The computers students worked on in all three studies were comparable. All computers worked with Windows XP, and used Internet Explorer version 6. The PhD-students and the freshmen used the same computer because they came to our laboratory. All the secondary educational students also worked on the same computer in our lab. The student teachers worked in a specially equipped computer room at the school. Therefore it is not expected that the equipment used in the different groups influenced the results. The experimenter watched the participants and communicated mainly to encourage him/her to keep on thinking aloud and answered questions if there were any. All tapes were typed-out into protocols. In all studies two trained raters scored the protocols.

The fact that the time spent on solving the information problem differed per group of students, could have an impact on the results. However, when looking closely at the time investment, it can be seen that the students who had to accomplishing the task in one and a half hour had to deliver the written product. The student teachers who worked for 1 h, delivered not the written product, but only an outline, and the secondary educational students searching for 1 h were not asked to make a kind of an outline, but were only asked to give a short answer twice. It is assumed that differences would especially occur between the group in the time spent on organizing and presenting the information.

The three studies were conducted with an interval of 2 years. So, the last data gathering was conducted 4 years after the first. Due to more sophisticated hardware or the increase of the amount of information on the WWW results could be biased. However, this was not an issue because the same kind of equipment was used in the different studies. The amount and kind of information available could also have an impact. At least for the first and second study it could be said that concerning the task about the perishableness of food, the researchers checked if the same reliable information was still on the WWW during the second experiment. This was the case.

4.5. Data analyses

In the first study the instrument used to score the protocols was developed and tested (Brand-Gruwel et al., 2005). Two trained raters scored all protocols and the video registrations simultaneously by using the coding system. The raters were trained in two sessions. In the first session, after clarifying the scoring system and discussion concerning the categories, one protocol was scored together and the use of the categories and codes in the system were discussed. Before the second session the raters scored two protocols and during the second session the inter-rater reliability was calculated and differences in scores were discussed. After the training the two raters scored six protocols together. The inter-rater reliability (Cohen's Kappa) was calculated for these protocols and the raters reached consensus on the statements they disagreed on. The average of the inter-rater reliabilities on the constituent skills, and regulation activities was .70 ($SD = .06$).

Time spent on the constituent skills was calculated taking into account time on task. Frequencies were calculated to gain insight in the used constituent skills, regulation activities and the conditional skills 'reading' and 'evaluating'. For the students of study 1 (PhD and freshmen) the frequencies of the skills were recalculated to a time span of 1 h. The frequencies of these students were divided by the amount of minutes spent and multiplied with 60 (60 min). For example, a student scanning a site 30 times in 70 min, got a reported frequency of $((30/70) * 60)$.

Differences between the groups on these variables were analysed using non-parametric tests. To gain insight in these differences between the four groups first Kruskall–Wallis tests for independent samples were used. In case of significant differences, the groups were pair wise compared using Mann–Whitney analysis. Because this analysis is used to test more hypotheses, the significant levels are reduced using a Bonferroni correction; the used significance level is $p < (0.5/3)$, which means $p < .015$.

To gain even more insight, time spent on the constituent skills was calculated and as an example of the iterative process the sequence of the used constituent skills of four students are visualized.

5. Results

5.1. Time investment in the constituent skills

Before going into the means and the standard deviations for the number of times a particular constituent skill or regulation activity was performed by the students, the average time spent on the constituent skills will be compared. Fig. 2 shows the time investment (corrected for time on the task) in the constituent skills by the different groups. A pie represents 1 h, and a piece of the pie represents the minutes spent on the skill involved. Because students time on task differed, time on the skills was recalculated (see Section 4.5).

As can be seen, none of the groups spent much of their time defining the problem. Secondary education students seem to spend more time searching for information on the WWW. They all invested the same amount of time to scan information It is noteworthy that secondary education students spent more time processing information and less time presenting it. This could be due to the type of assignment. Secondary education students were supposed to only write a short answer to the question.

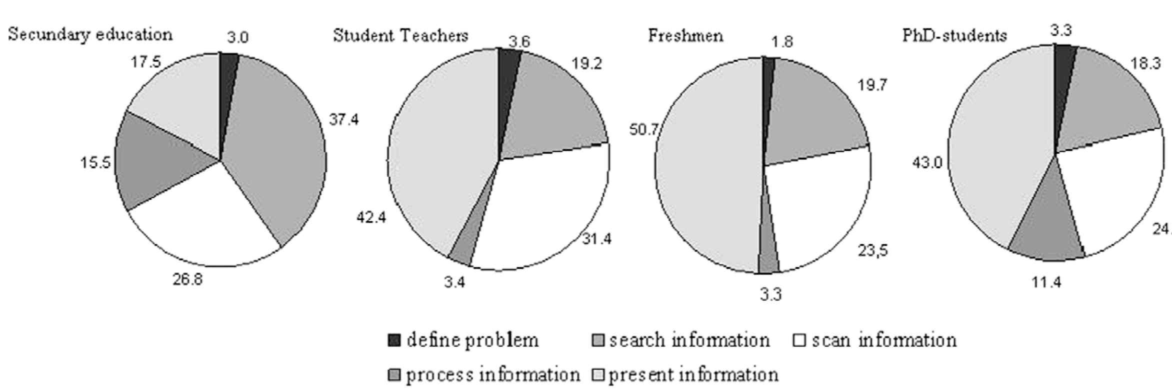

Fig. 2. Representation of differences in time invested in the constituent skills among PhD-students, psychology freshmen, student teachers, and secondary education students.

Although some differences on time investment on constituent skills seem to occur, one can say that the overall pattern of time investment is quite the same for the groups of students. Differences were not analysed statistically, because the tasks differed in the requirements concerning the product (essay, outline and short answer).

5.2. The constituent skills and regulation activities

Table 1 presents the means and the standard deviations for the number of times constituent skills and regulation activities were performed by the four groups of students.

It can be seen that the skill 'Define information problem' only occurred once, at the beginning of the task. When students looked back into the task description while accomplishing the task and, for instance, took notice of the task requirements, this was scored as orientation on the task (sub skills of the regulation variable 'Orientation') and not as define problem.

Looking at the differences between the groups using a Kruskal Wallis analysis, a significant difference was found on the constituent skill 'Search information', χ^2 (3, $N = 46$) = 30.76, $p < .001$. Additionally, the groups were pair-wise compared using Mann–Whitney analyses. These analyses revealed that the secondary education students search significantly more often than the other three groups of students: for PhD-students, $z = -3.42$, $p < .001$; for freshmen, $z = -3.22$, $p < .001$; for student teachers $z = -4.25$, $p < .001$. Besides, a difference was found between the PhD-students and the student teachers, $z = -2.84$, $p < .01$. Also on the variable 'Scan information' a significant difference was found between the four groups, χ^2 (3, $N = 46$) = 19.33, $p < .001$. Again Mann–Whitney analyses comparing the groups pair-wise showed that the secondary education students scanned significantly more than the PhD-students ($z = -2.83$, $p < .01$), freshmen ($z = -2.64$, $p < .01$), and the student teachers ($z = -2.49$, $p < .01$). A significant difference was also found between PhD-students and students teachers, $z = -3.01$, $p < .01$, and between freshmen and student teachers, $z = -2.66$, $p < .01$. A significant difference between the groups was found on 'Process information' as well: χ^2 (3, $N = 46$) = 16.41, $p < .001$. The secondary education students processed information more times during problem solving than student teachers ($z = -3.52$, $p < .001$) and freshmen ($z = -2.58$, $p < .01$). For 'Organizing and presenting information' the groups differed significantly, χ^2 (3, $N = 46$) = 15.2, $p < .001$. The pair-wise Mann–Whitney analyses revealed that the student teachers organized information more often and more often worked on presenting the information than the PhD-students ($z = -3.19$, $p < .001$) and the secondary education students ($z = -3.44$, $p < .001$).

What do these results mean? Overall, it is seen that the secondary education students search, scan, and process information more times during the process. This means that they switch more often between these different skills during the IPS-process, and show a more iterative process. The time intervals between different skills used are rather small and one can conclude that the process for these students is more rapid.

Concerning the regulation activities Kruskal–Wallis analysis revealed a significant difference between the groups, χ^2 (3, $N = 46$) = 30.39, $p < .001$. Pair-wise analyses revealed that the secondary education students regulate their ongoing process less than the freshmen ($z = -2.64$, $p < .01$), and the PhD-students ($z = -3.23$, $p < .001$). The freshmen regulated less than the student teachers ($z = -2.66$, $p < .01$). Concerning the regulation activities, differences between the groups were found on the variable 'monitor and steer', χ^2 (3, $N = 46$) = 33.85, $p < .001$. It seems that the secondary educational students monitored and steered their process less often than the PhD-students ($z = -3.60$, $p < .001$), student teachers ($z = -5.15$, $p < .001$), and freshmen ($z = -2.64$, $p < .01$). Also for the orientation on the process differences between the groups of students were found, χ^2 (3, $N = 46$) = 21.56, $p < .001$. The pair-wise analysis showed that the secondary educational students oriented less than the PhD-students ($z = -2.87$, $p < .01$), the student teachers ($z = -4.19$, $p < .001$), and the freshmen ($z = -2.83$, $p < .01$).

5.3. Sequence of used constituent skills: an example

As can be concluded from the frequencies of the used skills, the IPS-process is an iterative process. Fig. 3 shows, as an example, the sequence of used constituent skills and regulation activities of one PhD-student, one freshman, one student teacher and one student from secondary education.

It can be seen that there especially are many iterations between searching and scanning information, and that it concerns small time-bits. The length of these bits is not likely to be caused by differences in hardware since all students used similar equipment. Students organize and present information mainly at the end of the process. Furthermore, the PhD-student is a good example of a student who regulates the process extensively.

Table 1
Number of times PhD-students, psychology freshmen, student teachers and secondary education students went through a process (recalculated to a 1 h time span).

	PhD-students ($n = 5$)		Freshmen ($n = 5$)		St. teachers ($n = 15$)		Sec. edu. students ($n = 23$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Define information problem***	1.00	–	1.00	–	1.00	–	1.00	–
Search information***	7.00	3.50	11.03	5.91	17.44	6.14	41.74	17.84
Scan information***	8.91	3.57	10.56	5.59	23.37	7.48	36.35	20.67
Process information***	3.71	2.41	0.97	1.14	1.59	1.81	9.71	9.43
Organize and present info***	1.83	1.41	5.53	7.05	11.81	5.19	5.20	7.67
Total regulation***	22.11	9.44	13.03	5.04	20.83	3.66	5.39	5.19
Monitoring/steering***	13.99	3.59	7.81	4.60	13.82	3.11	2.00	2.65
Orientation***	5.68	4.29	2.83	1.42	5.32	3.08	0.82	1.80
Evaluating	2.44	2.01	2.38	2.09	1.69	1.70	2.58	4.94

*** $p < .001$

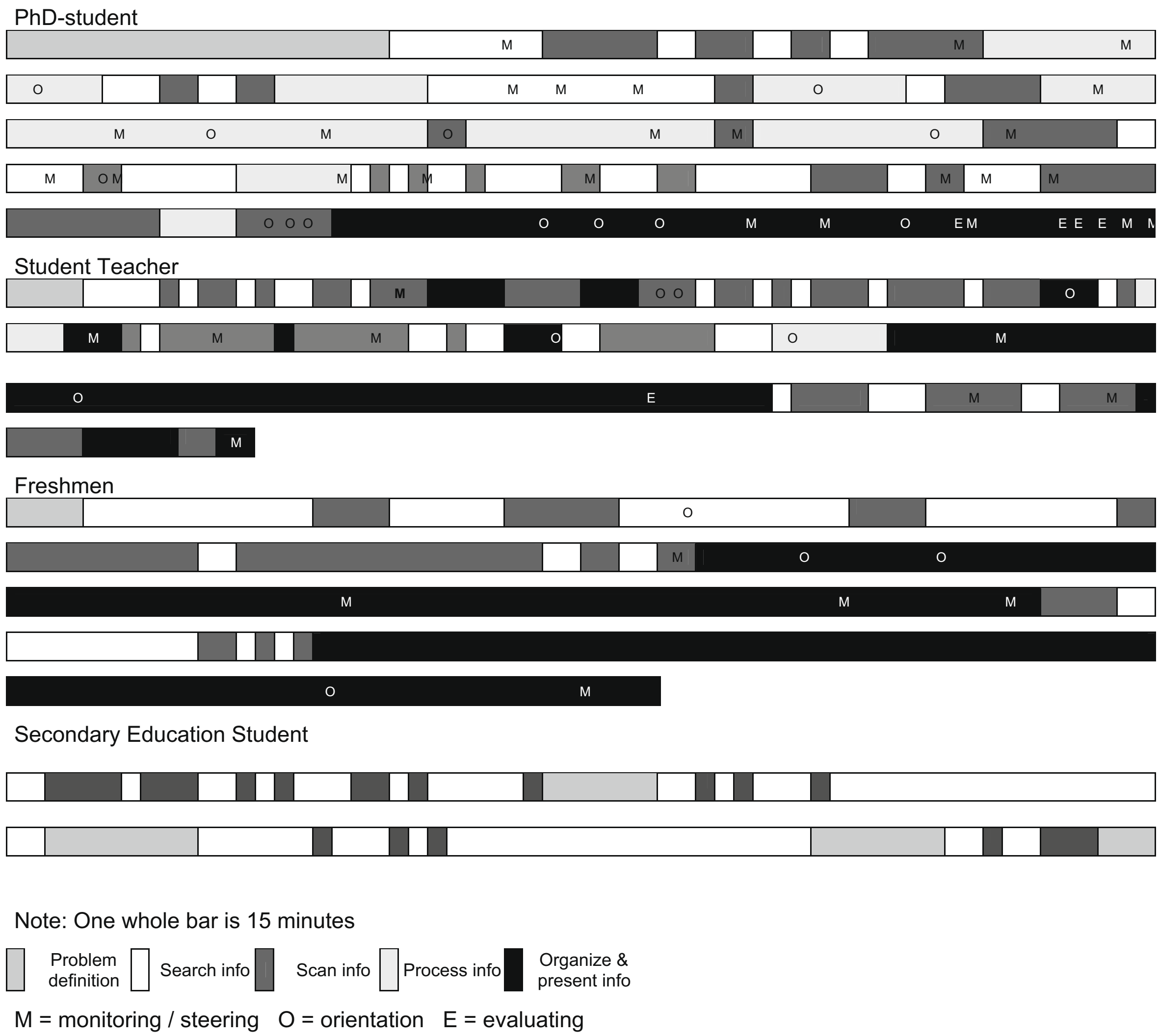

Fig. 3. Sequence of the used constituent skills and regulation activities.

5.4. Conditional skills

5.4.1. Reading

Table 2 presents the frequencies concerning how often students read in a more global manner (scanning) and more in-depth.

Concerning global reading, a significant difference was found between the groups, χ^2 (3, $N = 46$) = 8.14, $p < .05$. Pair-wise comparison between the groups showed no significant differences, taking into account the Bonferroni correction. Also on reading in depth a difference was found between the groups, χ^2 (3, $N = 46$) = 12.81, $p < .01$. Pair-wise Mann–Whitney comparison showed only a significant difference between the student teachers and the secondary educational students, $z = -3.13$, $p < .01$.

However, these frequencies do not say much about the time spent reading and about the quality of the process. It is obvious that global reading is important in the IPS process. Reading sites globally to look for usable information before reading it in-depth is a good strategy, because it is not possible to read all information with the same focus and make an adequate decision about the type of information. However, for meaningful learning it is important to read the relevant information in-depth. Reading comprehension strategies such as summarizing and questioning are essential as the following protocol of Tim shows.

Table 2
Number of times PhD-students, psychology freshmen, student teachers and secondary education students read information global or in depth (recalculated to a 1 h time span).

	PhD-students ($n = 5$)		Freshmen ($n = 5$)		St. teachers ($n = 15$)		Sec. edu. students ($n = 23$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Reading global*	19.10	5.55	20.39	10.00	30.93	9.91	34.31	17.68
Reading in depth**	6.41	6.10	1.81	2.04	2.23	2.43	10.12	11.61

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

Table 3
Number of times PhD-students, psychology freshmen, student teachers and secondary education students evaluated sources and information (recalculated to a 1 h time span).

	PhD-students ($n = 5$)		Freshmen ($n = 5$)		St. teachers ($n = 15$)		Sec. edu. students ($n = 23$)	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Evaluate sources*	.83	1.14	0.00	0.00	1.58	2.23	0.57	1.56
Evaluate information	9.11	6.64	5.85	2.11	5.79	4.84	13.47	10.83

* $p < .05$

TIM ...[after reading a paragraph about what should be on a label]... OK, most manufacturers put something like 'do not use three days after opening'. So, maybe it is a good idea to use this information for the argument I have to write. But, that is only one thing, now I need more information about what to do with this information. Can you really not eat the food after those days? Probably it depends on the product...[searching]...Ok, here it says that food that is out of date is not necessarily harmful for your health. The manufacturers use safe margins. You can eat it after the date, but the manufacturers do not guarantee. And here it also says that it depends on the product and that there are different types of decay. Ok, that is what I already thought...

5.4.2. Evaluation of results, sources and information

When evaluating one can evaluate the source (website), or evaluate the information. Table 3 presents the means and standard deviations of how often students evaluate these two kinds of aspects. Because time on task differed the means are recalculated to a time span of 1 h.

Kruskall–Wallis analyses revealed that between the groups a difference was only found with respect to the evaluation of sources (websites), χ^2 (3, $N = 46$) = 7.58, $p < .05$. No differences occurred between the number of evaluations of information. Mann–Whitney analyses were used to compare the groups pair-wise. Using the Bonferroni correction, no significant differences could be reported.

6. Conclusion and discussion

The purpose of this study was to gain insight in the different constituent skills, regulation activities, and conditional skills of the overall IPS-skill. The hypothesis was that students from different populations (teacher college, secondary education, psychology and PhD) all perform the five constituent skills: define information problem, search information, scan information, process information, and organize and present information. Results show that, indeed, the five skills were performed by all students and that also all students do to some extent regulate the process. This means that the five constituent skills and the regulation of the process can be seen as the constituent skills for the main skill called Information Problem Solving. Results also show that the process is iterative, and that students do switch between skills during the process.

The results concerning the different groups of students revealed that the secondary educational students search and scan more often than the other three groups of students (PhD-students, freshmen and student teachers). A closer look at the data reveals that the secondary educational students do have more iterations between search and scan, what means that they click faster on a link in the hitlist, after looking at the website, decide faster to go back to the hitlist and click on another link. Another important result of this comparison is the difference found in regulation activities. The secondary educational students monitor and steer, and also orient less during the process, than the other students. This is in line with research of Fidel et al. (1999) and Lyons et al. (1997). They also found that teenagers did not feel the need to plan a search or to check whether their planning was adequate.

It was hypothesized that the younger students (secondary education) would process information less in depth, but in our comparison, that was not the case. Secondary educational students spent a reasonable time studying the information. However, more research is needed in this matter, because the circumstances were not completely identical for all groups.

In the comparison between the students on evaluating sources and information no pair-wise significant differences between the groups of students were found. However, the study of Walraven et al. (2009) looked deeper into the evaluation criteria secondary education students use when evaluating sources and information. It was found that students appeared to use only a few criteria during IPS. Usability of *information* found on a site is often evaluated using the criterion 'connection to task'. This means that students seek information to answer the question, so the criterion is the relation to the asked question or task. Sometimes the language is a reason to determine if information is usable. Criteria of verifiability are hardly used to evaluate information. The *source* is mostly evaluated on its usability (do I think this source can provide an answer to the question). This is rather striking, because it is important to evaluate the reliability and the reputation.

Furthermore, differences between students can also be due to more or less computer skills and experience with internet. A study of Aslanidou and Menexes (2008) reveals that there is a relation between the age and the use of computers. Younger students do use the computer more than the older students. Moreover, students coming from a family environment with higher education and living in urban or semi-urban areas do have more access and are more experienced than others. In our studies students had different ages, but reported reasonable computer skills and were all living in an urban district, with good access to internet.

The model derived from the data is a model describing the skills needed to solve information problems when using internet to search the information. Compared to the search process model (Kuhlthau, 1993), the research process model (Stripling & Pitts, 1988), and the Big6-model (Eisenberg & Berkowitz, 1990) this is a curtailment, because it only focus on searching the WWW for information and leaves out other sources of information. On the other hand, because it focuses only on a specific source of information (the WWW), it gives a more in-depth insight in the processes involved. This can be seen as the added value of this IPS-I-model.

Another added value of the IPS-I-model is the emphasis on regulation. Keeping track of one's own search process and steering this process when necessary is important for solving information problems successfully. This regulation is closely related to the feelings involved in the search process as mentioned by Kuhlthau (2004). Having the feeling of frustration during the process will make students aware of the fact that steering is necessary and action must be taken to change negative feelings.

The IPS-I-model is based on 48 protocols of four types of students: students from a teacher training college, freshmen in Psychology, PhD students and secondary educational students. This combination of data of different studies gave us more evidence concerning how the IPS-process unfolds for adolescents and adults. The question is whether constituent skills and the sub-skills also occur when younger children (primary education) solve information problems, not only in the sense of the used skills, but also to gain more insight in the lacuna in their performance. Different studies (Fidel et al., 1999; Lyons et al., 1997) show, for instance, that activating prior knowledge, clarifying task requirements and determining needed information is difficult for teenagers and younger children. Insights in these difficulties offer the instructional designers the opportunity to design IPS-instruction that is tailor-made and fit the students' needs.

This leads to the next topic: design of IPS-instruction. Instruction to foster the IPS-skills should address the skills depicted in the model, but should especially focus on defining the information problem, processing information, judging the quality of sources and information, and regulation, because these skills seem the most difficult ones. However, it is possible that, depending on the target group, certain sub-skills do not need to be trained because students already master these skills. Looking at the sub-skills of solving information problems, one may decide not to provide training in computer skills, because students already possess this sub-skill. However, it should be ensured during the IPS-training that transfer of the learned skills occurs.

Different successful studies are conducted to teach students aspects of the IPS process. For instance, research of Saito and Miwa (2007) revealed that support concerning reflective activities and using visualizations helps to foster their search performance and conceptions about important search activities. Research of Stadtler and Bromme (2008) provided adults with little medical knowledge with evaluation and monitoring prompts while searching the WWW on a medical topic. For this purpose, the metacognitive tool met.a.ware was developed. Results showed that prompts for monitoring and evaluation increased knowledge on content and sources, and ontological classification helped to structure notes and focused participants on important ontological categories.

Concerning designing instruction, the results of the study described in this manuscript show that the constituent skills and sub-skills involved in IPS are highly interrelated, and are performed in an iterative fashion. Therefore, a *whole-task approach* is recommended for teaching the IPS-skill. In such an approach, students start with very simple versions of the whole task, enabling them to learn to coordinate and integrate the different skills involved. Within this approach, it is advisable to make a sequence that emphasizes particular constituent skills or clusters of sub-skills in different phases of the training (i.e., an emphasis manipulation approach; Van Merriënboer, 1997).

Moreover, to foster the transfer of the skill it is important to embed the instruction in the curriculum and make sure that in different settings the skill can be learned and used properly. Not only learning in different settings and embedded instruction in the curriculum is important for transfer, but also the emphasis on the strategic or heuristic information involved. For instance, a rich knowledge base about certain strategies or knowledge about what criteria can be used when judging sources and information under certain circumstances is important for transferring the skill to different settings.

Future research should address the issue of how IPS-instruction can best be designed to foster students IPS-skill in different situations.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.compedu.2009.06.004.

References

Aslanidou, S., & Menexes, G. (2008). Youth and the internet: Uses and practices in the home. *Computers and Education, 51*, 1375–1391.

Bilal, D. (2000). Children's use of the Yahooligans! Web search engine: I. Cognitive, physical, and affective behaviors on fact-based search tasks. *Journal of the American Society of Information Science, 51*, 646–665.

Branch, J. L. (2001). Junior high students and thinks alouds: Generating information-seeking process data using concurrent verbal protocols. *Library and Information Science Research, 23*, 107–122.

Brand-Gruwel, S., Aarnoutse, C. A. J., & Van den Bos, K. P. (1998). Improving text comprehension strategies in reading and listening settings. *Learning and Instruction, 8*, 63–81.

Brand-Gruwel, S., & Wopereis, I. (2006). Integration of the information problem-solving skill in a curriculum: The effects of learning with authentic tasks. *Technology, Instruction, Cognition and Learning, 4*, 243–263.

Brand-Gruwel, S., Wopereis, I., & Vermetten, Y. (2005). Information problem solving by experts and novices: Analysis of a complex cognitive skill. *Computers in Human Behavior, 21*, 487–508.

Coiro, J. (2003). Reaching comprehension on the internet: Expanding our understanding of reading comprehension to encompass new literacies. *The Reading Teacher, 56*, 458–464.

Duijkers, H. M., Gulikers-Dinjens, M. T. H., & Boshuizen, H. P. A. (2001). Begeleiden van leerlingen bij het zoeken, selecteren en beoordelen van informatie [supporting students when searching, selecting, and judging information]. In J. Ahlers, T. Hoogbergen, P. Leenheer, & J. de Vos (Eds.), *Handboek Studiehuis Tweede Fase* (pp. 1–34). Alphen a/d Rijn: Samsom.

Eisenberg, M. B. (2006). *A Big6™ skills overview*. <http://www.big6.com/showarticle.php?id=16>. Retrieved October, 2007.

Eisenberg, M. B., & Berkowitz, R. E. (1990). *Information problem-solving: The big six skills approach to library and information skills instruction*. Norwood, NJ: Ablex.

Fidel, R., Davies, R. K., Douglass, M. H., Holder, J. K., Hopkins, C. J., Kushner, E. J., et al. (1999). A visit to the information mall: Web searching behavior of high school students. *Journal of the American Society of Information Science, 50*, 24–37.

Fiderio, J. (1988). A grand vision: Hypertext mimics the braińs ability to access information quickly and intuitively by reference. *BYTE, 13*, 237–242.

Fredin, E. (1997). Rethinking the news story for the Internet: Hyperstory prototypes and a model of the user. *Journalism and Mass Communication Monographs, 163*, 1–47.

Grimes, D. J., & Boening, C. H. (2001). Worries with the Web: A look at student use of Web resources. *College and Research Libraries, 62*(1), 11–23.

Hill, J. R. (1999). A conceptual framework for understanding information seeking in open-ended information services. *Educational Technology, Research and Development, 47*(1), 5–27.

Hill, J. R., & Hannafin, M. J. (1997). Cognitive strategies and learning from the World Wide Web. *Educational Technology, Research and Development, 45*(4), 37–64.

Hirsch, S. G. (1999). Children's relevance criteria and information seeking on electronic resources. *Journal of the American Society for Information Science, 50*, 1265–1283.

Hölscher, C., & Strube, G. (2000). Web search behavior of Internet experts and newbies. *Computer Networks, 33*, 337–346.

Jacobson, M. J., & Spiro, R. J. (1995). Hypertext learning environments, cognitive flexibility, and the transfer of complex knowledge: An empirical investigation. *Journal of Educational Computing Research, 12*, 301–333.

Kafai, Y., & Bates, M. J. (1997). Internet web-searching instruction in the elementary classroom: Building a foundation for information literacy. *School Library Media Quarterly, 25*, 103–111.

Kicken, W., Brand-Gruwel, S., & Van Merriënboer, J. J. G. (2008). Scaffolding advice on task selection: A safe path toward self-directed learning in on-demand education. *Journal of Vocational Education and Training, 60*(3), 223–239.

Koot, U., & Hoveijn, M. (2005). Google, de magische antwoordmachine [google, the magical answermachine]. *Pedagogiek in Praktijk, 11*(28), 18–22.

Kuhlthau, C. (1993). *Seeking meaning: A process approach to library and information services*. Norwood, NJ: Ablex.

Kuhlthau, C. (2004). *Seeking meaning: A process approach to library and information services* (2nd ed.). Westport: Libraries Unlimited.

Land, S. M., & Greene, B. A. (2000). Project-based learning with the World Wide Web: A qualitative study of resource integration. *Educational Technology, Research and Development, 48*(1), 45–68.
Large, A., & Beheshti, J. (2000). The web as a classroom resource: Reaction from the users. *Journal of the American Society of Information Science, 51*, 1069–1080.
Lazonder, A. W. (2000). Exploring novice users' training needs in searching information on the WWW. *Journal of Computer Assisted Learning, 16*, 326–335.
Lazonder, A. W., Biemans, H. J. A., & Wopereis, I. G. J. H. (2000). Differences between novice and experienced users in searching information on the World Wide Web. *Journal of the American Society for Information Science, 51*, 576–581.
Leu, D. J., Jr, Kinzer, C. K., Coiro, J., & Cammack, D. (2004). *Toward a theory of new literacies emerging from the internet and other ICT*. Newark: International Reading Association.
Lorenzen, M. (2002). The land of confusion? – High school students and their use of the World Wide Web for research. *Research Strategies*, *18*, 151–163. <http://www.libraryinstruction.com/confusion.html>. Retrieved 07.09.2006.
Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-directed learning in problem based learning and its relationships with self-regulated learning. *Educational Psychologist Review, 20*, 411–427.
Lyons, D., Hoffman, J., Krajcik, J., & Soloway, E. (1997). An investigation of the use of the World Wide Web for on-line inquiry in a science classroom. Paper presented at the meeting of the national association for research in science teaching, Chicago, IL.
MaKinster, J. G., Beghetto, R. A., & Plucker, J. A. (2002). Why can't I find Newton's third law? Case studies of students' use of the web as a science resource. *Journal of Science Education and Technology, 11*, 155–172.
Marchionini, G. (1995). *Information-seeking in electronic environments*. New York: Cambridge University Press.
Marchionini, G. (1999). Educating responsible citizens in the information society. *Educational Technology, 39*(2), 17–26.
Miles, M. B., & Huberman, A. M. (1994). *Qulitative data analyses: An expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.
Moore, P. (1995). Information problem solving: A wider view of library skills. *Contemporary Educational Psychology, 20*, 1–31.
Mosenthal, P. B. (1998). Defining prose task characteristics for use in computer-adaptive testing and instruction. *American Educational Research Journal, 35*, 269–307.
Oliver, R., & Perzylo, L. (1994). Children's information skills: Making effective use of multimedia sources. *Educational and Training Technology International, 31*, 213–230.
Rothenberg, D. (1998). How the Web destroys student research papers. *Education Digest, 63*, 59–61.
Rouet, J. F., & Levonen, J. J. (1996). Studying and learning with hypertext: Empirical studies and their implications. In J. F. Rouet, J. J. Levonen, A. Dillon, & R. J. Spiro (Eds.), *Hypertext and Cognition* (pp. 9–36). Mahwah, NJ: Erlbaum.
Saito, H., & Miwa, K. (2007). Construction of a learning environment supporting learners' reflection: A case of information seeking on the web. *Computers and Education, 49*, 214–229.
Schacter, J., Chung, G. K. W. K., & Dorr, A. (1998). Children's internet searching on complex problems: Performance and process analyses. *Journal of the American Society for Information Science, 49*, 840–849.
Schmeck, R. R., & Geisler-Brenstein, E. (1989). Individual differences that affect the way students approach learning. *Learning and Individual Differences, 1*, 85–124.
Spiro, R. J., & Jehng, J. C. (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter. In D. Nix & R. J. Spiro (Eds.), *Cognition, education, and multimedia: Exploring ideas in high technology* (pp. 163–205). Hillsdale, NJ: Lawrence Erlbaum.
Stadtler, M., & Bromme, R. (2008). Effects of the metacognitive computer-tool met. a. ware on the web search of laypersons. *Computers in Human Behavior, 24*, 716–737.
Stripling, B., & Pitts, J. (1988). *Brainstorms and blueprints: Teaching library research as a thinking process*. Littleton, CO: Libraries Unlimited.
Sutcliffe, A., & Ennis, M. (1998). Towards a cognitive theory of information retrieval. *Interacting with Computers, 10*, 321–351.
Tu, Y., Shih, M., & Tsai, C. (2008). Eighth graders' web searching strategies and outcomes: The role of task types, web experiences and epistemological beliefs. *Computers and Education, 51*, 1142–1153.
Van Merriënboer, J. J. G. (1997). *Training complex cognitive skills*. Englewood Cliffs, NJ: Educational Technology.
Wallace, R. M., Kupperman, J., Krajcik, J., & Soloway, E. (2000). Science on the web: Students online in a sixth-grade classroom. *The Journal of the Learning Sciences, 9*, 75–104.
Walraven, A., Brand-Gruwel, S., & Boshuizen, H. P. A. (2008). Information problem solving: A review of problems students encounter and instructional solutions. *Computers in Human Behavior, 24*, 623–648.
Walraven, A., Brand-Gruwel, S., & Boshuizen, H. P. A. (2009). How students evaluate information and sources when searching the World Wide Web for information. *Computers and Education, 52*, 234–246.
Wolf, S. E., Brush, T., & Saye, J. (2003). Using an information problem-solving model as a metacognitive scaffold for multimedia-supported information-based problems. *Journal of Research on Technology in Education, 35*, 321–341.
Wopereis, I., Brand-Gruwel, S., & Vermetten, Y. (2008). The effect of embedded instruction on solving information problems. *Computers in Human Behavior, 24*, 738–752.
Yang, S. (1997). Information seeking as problem solving using a qualitative approach to uncover the novice learners' information-seeking processes in a Perseus hypertext system. *Library and Information Science Research, 19*, 71–92.
Zins, C. (2000). Success, a structured search strategy: Rationale, principles, and implications. *Journal of the American Society for Information Science, 51*, 1232–1247.