A longitudinal study on information-seeking knowledge in psychology undergraduates: Exploring the role of information literacy instruction and working memory capacity

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Abstract

No longitudinal studies on whether the acquisition information literacy requires formal instruction or whether it just develops "naturally" have yet been published. Moreover, no studies exist on individual and situational factors moderating the long-term development of information literacy. For these reasons, a three-semester long, four-wave longitudinal study on information-seeking knowledge (a major aspect of information literacy) was conducted with 137 psychology undergraduates (first wave). With regard to situational factors, curriculum-embedded information literacy instruction was contrasted with library instruction. Concerning individual factors, the role of working memory capacity was explored on cognitive load theory grounds. Data were analyzed through multi-level modeling. Results revealed a linear increase in information-seeking knowledge across the four waves, which remained significant when controlling for the effects of information literacy instruction. Curriculum-embedded instruction seemed more effective than library instruction. Working memory capacity moderated the development of information-seeking knowledge: Students with a high working memory capacity had steeper learning curves than those with lower working memory capacity. Results were robust when controlling for additional individual factors known to have an impact on knowledge development, namely fluid intelligence, epistemic beliefs, and domain-specific self-efficacy beliefs. We conclude that instruction plays a key role in information literacy development, especially when it is embedded into the respective curriculum. Moreover, reducing cognitive load is crucial for the acquisition of information-seeking knowledge. Efforts should therefore be made to enhance the usability of information search tools and to provide well-structured online tutorials and instructional modules, for example by using authentic, real-world learning tasks.

Keywords: media in education; post-secondary education; teaching/learning strategies; human-computer interface;

1   Introduction

Information literacy is commonly defined as a set of skills and abilities that enable individuals to recognize an information need and to effectively locate, evaluate, and use the needed information (Association of College & Research Libraries, 2000[1]). Information-seeking knowledge refers to declarative and procedural knowledge on how to search for information and therefore constitutes an important prerequisite for information literate behavior[2] (Rosman, Mayer, & Krampen, 2015a). Since it enables an active construction (instead of passive reception) of knowledge, many authors have emphasized the crucial role of information literacy for conceptual understanding and self-regulated learning (Brand-Gruwel, Wopereis, & Vermetten, 2005; Johnston & Webber, 2003; Joo, Bong, & Choi, 2000; Tsai, Hsu, & Tsai, 2012). While the majority of publications on information literacy consists of practitioner-oriented theoretical papers or case studies offering prescriptive advice (e.g., on how to design and implement information literacy instruction; Larkin & Pines, 2005), only one longitudinal study on the development of information literacy has been published until now (Salisbury, Corbin, & Peseta, 2013). Since this study took place in an environment where students received continuous information literacy instruction, it does not allow to ascertain

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[1] The information literacy standards by the Association of College & Research Libraries were revised between 2013 and 2015 and now form a broader and more flexible *framework* using so-called threshold concepts (i.e., "ideas in any discipline that are passageways or portals to enlarged understanding or ways of thinking and practicing within that discipline"; Association of College & Research Libraries, 2015, p. 2). In terms of the 2015 framework, the present article mainly relates to the concept of "*searching as strategic exploration*".

[2] Most studies investigating "information literacy" in fact use measures (i.e., multiple-choice tests) that primarily assess information-seeking knowledge. To explicitly measure information-seeking *skills*, performance measures (e.g., portfolios or information search tasks) have to be used.

whether information literacy necessarily requires formal instruction or whether it just develops "naturally" (e.g., through more or less systematic self-regulated learning activities) in today's so-called *digital native* students (Ng, 2012). Moreover, no longitudinal studies on the (situational and individual) moderating factors of information literacy development have – to our knowledge – been published yet. With regard to situational factors that likely influence the development of information literacy, many emphasize the superiority of curriculum-embedded and domain-specific information literacy instruction over more generic and domain-unspecific instructional methods (e.g., Andretta, 2005). Nevertheless, this assumption has not yet been tested empirically. As for individual determinants of information literate behavior, working memory capacity has been prominent for quite some time (e.g., Garcia, Nussbaum, & Preiss, 2011; Savolainen, 2015). On the other hand, no studies exist on how this variable might influence the development of information-seeking knowledge. The present article fills these gaps by investigating the development of information-seeking knowledge in psychology students over the first half of their undergraduate studies and by relating development to these situational and individual factors.

1.1 Information literacy development

The transition from secondary to tertiary education constitutes a cornerstone in students' intellectual development and a turning point in how they (should) approach academic information seeking. Even though some secondary schools already convey basic information-seeking knowledge, universities are the places where most students get in touch with scholarly information-seeking for their first time. Simply consulting Google^{TM} is replaced by searches in academic search engines and bibliographic databases, the breadth and depth of Wikipedia^{TM} becomes insufficient for many purposes, and lecturers increasingly require students to read scholarly books or even journal articles. This is especially true for the

psychology curriculum, where information literacy is viewed as a central learning goal (American Psychological Association, 2013).

Notwithstanding the importance of this transitional phase, longitudinal studies on information literacy development in freshmen and sophomores are rare. Apart from qualitative research (e.g., Chu & Law, 2008; MacMillan, 2009; Warwick, Rimmer, Blandford, Gow, & Buchanan, 2009) most studies investigate – predominately in pretest-posttest-designs – the effects of library or course instruction on information literacy (e.g., Burkhardt, 2007; Leichner, Peter, Mayer, & Krampen, 2014; Wopereis, Brand-Gruwel, & Vermetten, 2008) or on other variables related to information-seeking (e.g., library satisfaction: Stamatoplos & Mackoy, 1998; cognitive states: Walton & Hepworth, 2011). Other studies longitudinally investigate the search process as such (e.g., Kuhlthau, 2004; Spink, Wilson, Ford, Foster, & Ellis, 2002; Vakkari, 2001). For example, Spink and colleagues (2002) let their participants carry out actual information searches and collected standardized interview data prior to and after the searches. However, the results of these studies do not allow for conclusions about the long-term development of information literacy. In contrast, a third group of studies investigates information-seeking in a truly longitudinal fashion (i.e., over sufficiently long intervals). Unfortunately, these studies are extremely rare and most of them investigate information-seeking on a rather basic level by only considering students' library use patterns (Whitmire, 2001) or the use and awareness of electronic information services (Crawford, De Vicente, & Clink, 2004; Urquhart & Rowley, 2007). As they do not employ achievement tests to assess information literacy, such studies might perhaps better be conceptualized as longitudinal investigations of individual information behavior in library contexts.

One recent article by Salisbury et al. (2013) stands out in this taxonomy. In their four-wave longitudinal study, the authors used an established information literacy test (the so-called Research Practices Survey [RPS]; Higher Education Data Sharing Consortium, 2015) to

investigate health sciences students' information literacy development in the context of curriculum-embedded information literacy instruction. Even though the study exhibits some rather severe methodological shortcomings (e.g., a dropout of over 90 percent across the study period, no inferential testing), the authors conclude that their data "clearly indicates improvement between first and final year for learning outcomes related to understanding peer-review (sic) articles, understanding citations, utilisation of academic sources and competence in applying information search skills" (Salisbury et al., 2013, p. 8). When interpreting the results of Salisbury et al. (2013), one nevertheless has to bear in mind that all study participants received continuous information literacy instruction throughout the whole three-year study period. Therefore, the question arises whether their information-seeking skills would also have increased *without* specific training, especially since the participants had distinctly higher RPS scores in the last wave than students from other universities.

Our first point of investigation therefore deals with whether or not psychology studies stimulate – independent of formal information literacy instruction – the development of information-seeking knowledge in psychology undergraduates. Even though empirical evidence on this is scarce, there seems to be some agreement that information literacy does not necessarily develop on its own. For example, Brophy and Bawden (2005) see formal instruction as a crucial requirement for information literacy development. In line with this, Warwick et al. (2009) argue that many students employ "a conservative information strategy, retaining established strategies as far as possible and completing tasks with minimum information seeking effort" (p. 2402). As information literacy instruction is not integrated into most educational curricula (Derakhshan & Singh, 2011; Probert, 2009; Schmidt-Hertha & Rott, 2014) and students rarely participate in library instruction (Head & Eisenberg, 2009), this might well explain why even advanced students often refer to Google (e.g., Griffiths & Brophy, 2005) and employ one-word-searches (e.g., Sutcliffe, Ennis, & Watkinson, 2000) when searching for scholarly literature.

On the other hand, one might argue that at least in psychology, many classroom assignments require information-seeking (e.g., to prepare term papers) and that students therefore acquire the respective skills through more or less systematic self-regulated learning activities, for example by conducting trial-and-error searches, consulting online tutorials, or seeking advice from their peers, faculty, or librarians (Head & Eisenberg, 2009). In line with this, Gross and Latham (2009) found undergraduates to consider their information-seeking skills to be primarily "self-taught". Moreover, Elmborg (2003) argues that "all researchers know that trial-and-error searching in online indexes and exploring the stacks can be potent learning experiences in and of themselves" (p. 70). Finally, Head and Eisenberg (2009) found most of their study participants – even though only 12 percent had ever undergone library instruction – to use scholarly databases on a regular basis. One may thus conclude that many students acquire some less elaborate search strategies on their own and subsequently use them both in everyday and in course-related searches (Head & Eisenberg, 2009). Considering this, formal instruction would not always be necessary, at least with regard to the development of basic search strategies. We thus expect psychology undergraduates to develop at least some information-seeking skills independently of formal instruction:

Hypothesis 1: Psychology undergraduates' information-seeking knowledge increases over their first three semesters even when controlling for the effects of formal information literacy instruction.

1.2 Effects of different types of information literacy instruction

As a second line of investigation, we considered the effects of situational factors on information-seeking knowledge development. Although participation in information literacy instruction is not mandatory at most universities, some students may either choose to participate in generic instruction offered by libraries or may receive more or less extensive instruction during their domain-specific courses. Library instruction often consists of so-

called "one-shot" sessions, usually lasting 45 to 90 minutes. Such classes aim at conveying general information-seeking skills (e.g., skills relating to the use of library catalogues or bibliographic databases) and are often rather generic and domain-unspecific (i.e., not tailored to information-seeking in a specific domain). One-shot library sessions have been widely criticized since they only teach basic knowledge on certain library services and do not allow to transfer this knowledge to actual, real-world searches (Anderson & May, 2010; Mery, Newby, & Peng, 2012).

Embedding these same learning goals (i.e., fostering information-seeking skills) into discipline-specific curricular courses, in contrast, might be helpful to achieve deeper processing of learning contents and thus better and more sustainable learning. So-called *embedded designs* (Andretta, 2005) therefore not only allow learners to acquire discipline-specific knowledge about databases and library catalogues, but also encourage (or even require) the transfer of learning contents to real-world searches, for example by letting students carry out literature searches on self-chosen topics and summarize the results in seminar papers. Andretta (2005) views such designs as most effective because they allow learners not only to acquire new skills, but also to reflect on and implement the newly acquired skills in novel contexts. Embedded designs thus have strong similarities with contemporary instructional design methodologies like the Four-Component Instructional Design model (4C/ID-model; van Merriënboer & Kirschner, 2013), in which authentic, real-world learning tasks are the method of choice. Especially in the long term, students will likely benefit more from a research methods course that combines authentic information-seeking tasks with the writing of a seminar paper than from an extracurricular instruction session that conveys generic knowledge on how to use certain library services (Artman, Frisicaro-Pawlowski, & Monge, 2010). We therefore expect curriculum-embedded information literacy instruction to have stronger effects on the development of information-seeking knowledge than generic library instruction.

Hypothesis 2: Curriculum-embedded information literacy instruction has a stronger effect on the development of information-seeking knowledge than library instruction.

1.3 Relations with working memory capacity

A third point of investigation deals with individual factors that might moderate the development of information-seeking knowledge. In recent years, cognitive load theory (Paas, Renkl, & Sweller, 2003) has become immensely popular in multimedia and computer-mediated learning. According to cognitive load theory, human working memory – defined as a cognitive system that is used for temporarily storing and manipulating information (Baddeley, 2012) – is not able to process many elements simultaneously. Working memory overload, in turn, impedes the transfer of new information to long-term memory (e.g., through schema acquisition and automation) and thus impairs learning (Paas et al., 2003; van Merriënboer & Sweller, 2005). Paas et al. (2003) distinguish three types of cognitive load: *Intrinsic* cognitive load relates to demands that are imposed on working memory capacity by the learning content itself (e.g., by the level of interactivity between different learning elements). *Extraneous* (or ineffective) cognitive load, in contrast, are working memory demands imposed by ineffective instructional design (e.g., when problem solutions are not given in the instruction but have to be derived by the learner). Finally, *germane* (or effective) cognitive load is working memory load directly relevant to learning (e.g., schema acquisition and automation).

Bartholomé and Bromme (2009) suggest that a high working memory capacity enables learners to better deal with cognitive load. In line with this, previous research has established a strong relationship between working memory capacity and learning (Austin, 2009; Carretti, Borella, Cornoldi, & De Beni, 2009; Engle, 2002; Gathercole, Brown, & Pickering, 2003; Seufert, Schütze, & Brünken, 2009). Because it keeps users orientated while navigating and searching, working memory capacity also plays a crucial role in information-seeking. For example, Sharit, Hernández, Czaja, and Pirolli (2008) argue that navigational behavior

requires "both recall of where one is, planning of where one wants to go, and comprehension of information on Web pages … to be carried out more or less concurrently" (p. 20). Positive effects of working memory capacity on information-seeking have been found in very diverse samples (e.g., Czaja, Sharit, Ownby, Roth, & Nair, 2001; Garcia et al., 2011; Laberge & Scialfa, 2005; Savolainen, 2015). With regard to cognitive load theory, such findings suggest that the multitude of functions and the complex hyperspace structure of most academic search engines and bibliographic databases induce high amounts of intrinsic cognitive load that overtax searchers with lower working memory capacity. For example, research shows that learners with lower working memory capacity are quickly overwhelmed by hypertext environments (DeStefano & LeFevre, 2007) and easily diverted by irrelevant details (seductive details effect; Mayer, Heiser, & Lonn, 2001; Sanchez & Wiley, 2006).

Despite robust evidence for the effects of working memory capacity on information-seeking, empirical and/or theoretical articles on how working memory capacity might affect the *development* of information-seeking skills have not yet been published. This is striking, because cognitive load theory is even better suited to explain why students with lower working memory capacity might have difficulties in acquiring information-seeking skills. In fact, these students face a double burden since they are prone to be overwhelmed by both the learning process as such (i.e., instructional methods inducing extraneous cognitive load) and by the learning contents (e.g., complex database structures inducing intrinsic cognitive load; see above). Since extraneous and intrinsic cognitive load are additive (Paas et al., 2003), this might especially be true when such students approach information-seeking outside of formal instruction. In this case, they have to navigate through a complex information environment (e.g., online tutorials, bibliographic databases, etc.) while at the same time managing their self-regulated learning process (e.g., extrapolating different search strategies, evaluating their value, memorizing them, etc.), thus inducing high intrinsic *and* high extraneous cognitive load, which further impairs the transfer of new information to long-term memory.

On the other hand, students with a high working memory capacity will likely be more successful in assimilating new information from information literacy instruction and tutorials, and will not be overwhelmed by the multitude of functions and the complex hyperspace structure of most search tools. In sum, we therefore expect students with higher working memory capacity to have steeper learning curves with regard to the development of their information-seeking knowledge.

Hypothesis 3: Working memory capacity predicts the development of information-seeking knowledge in psychology undergraduates over their first three semesters: The higher students' working memory capacity, the higher their increase in information-seeking knowledge will be.

1.4 Summary of hypotheses

To sum up, we suggest the following hypotheses:

Hypothesis 1: Psychology undergraduates' information-seeking knowledge increases over their first three semesters even when controlling for the effects of formal information literacy instruction.

Hypothesis 2: Curriculum-embedded information literacy instruction has a stronger effect on the development of information-seeking knowledge than library instruction.

Hypothesis 3: Working memory capacity predicts the development of information-seeking knowledge in psychology undergraduates over their first three semesters: The higher students' working memory capacity, the higher their increase in information-seeking knowledge will be.

2   Materials and methods

2.1 Participants and procedure

All hypotheses were tested with data from a four-wave longitudinal study on knowledge development. Participants were psychology undergraduates seeking a Bachelor's degree. Baseline data was collected during the first few weeks of participants' studies, followed by three consecutive data collection sessions at the beginning of the second, third, and fourth semesters, respectively. The study thus spanned across the first half of the psychology undergraduate curriculum. We ensured that only psychology undergraduates participated in the study by investigating enrollment lists. To reduce dropout, participants were financially compensated.

Data were collected in groups of 2 to 25 participants[3] in various computer labs[4] of a large German university. One-hundred-thirty-seven students (approximately 80 percent of that particular cohort) participated in the first wave (t1) of the study. At baseline, participants were 82 percent females and $M = 20.43$ ($SD = 2.53$) years old. Participants who had missed one of the consecutive waves (e.g., second wave) nevertheless were invited to participate in the next wave (e.g., third wave). Only one participant made use of that option. Notwithstanding this, dropout was rather low with 16 percent over the whole study period. Differences between the dropout- and the non-dropout-group were – due to the strong sample size differences in both groups and possible unequal distributions – investigated by means of Mann-Whitney U tests. No significant differences were found with regard to age, sex (via chi-square test), secondary

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[3] In four instances, data were collected in individual sessions (one single participant) because students' schedules did not allow participation in the group sessions.

[4] The control variables *epistemic beliefs* and *information literacy self-efficacy* were collected in an at-home module.

school GPA, baseline information-seeking knowledge, working memory capacity, intelligence, and various self-report measures (e.g., information literacy self-efficacy, academic self-concept, epistemic beliefs). We therefore conclude dropout to have occurred unsystematically.

2.2 Measures

The test battery was administered in an online format which included a feature that warned participants if they had forgotten to respond to an item. The amount of missing data was therefore – apart from the longitudinal dropout – very low.

The *demographics* section of the t4 test battery included a question about whether students had at least once participated in an instructional course by the university library (simple guided library tours not included; yes/no response format). These courses are taught by librarians and usually consist of a generic, hands-on introduction to the library catalogue and to bibliographic databases available at the university library. Moreover, the curriculum of one freshmen course during the first or second semester includes an introduction to research methods and deals with, among others, behavioral observation, empirical hypothesis testing, and scholarly information-seeking. Even though this small-group course is mandatory for all freshmen, lecturers are free to decide on the specific contents, teaching methods, and weighting of the course topics. Nevertheless, all students are required to develop research questions and hypotheses based on existing literature, to collect and analyse observational data to test these hypotheses, and to write a research report. Particularly deriving the hypotheses and drafting the report requires a considerable amount of scholarly information-seeking. The amount of information literacy instruction given to support these processes varies greatly across different lecturers, and participants are randomly assigned to their respective course and lecturer. At t3, students were asked to what extent information-seeking and bibliographic skills were covered in their respective course (e.g., "How extensively did

your course cover literature searches in bibliographic databases?"). Three corresponding questions referring to bibliographic databases (see sample item), academic search engines (e.g., Google Scholar[TM]), and citation skills were to be answered on a 6-point scale ranging from "not at all" to "more than six hours".

Information-seeking knowledge was measured with the Procedural Information-Seeking Knowledge Test – Psychology Version (PIKE-P; Rosman et al., 2015a) at all four measurement waves. Based on a situational judgment test format, the test aims at measuring both declarative and procedural knowledge about various aspects of information-seeking (e.g., knowledge about publication types, generation of search keywords, use of limiters and Boolean operators, etc.). The test has the advantage that "subjects are not asked about specific features of specific databases, but about global functions that nearly all these databases possess (e.g., limiters or online thesaurus)" (Rosman et al., 2015a, p. 8). It thus allows for a higher generalizability of findings in contrast to more database- or interface-specific inventories (e.g., Cameron, Wise, & Lottridge, 2007). The tests' 22 items present different situations that frequently come about during an information search (e.g., 'You are looking for a 1964 article of Heinz Heckhausen in a reference database. Unfortunately, you forgot the name of the article. How do you proceed in order to find it out swiftly?'). Each situation is complemented by four response alternatives describing different approaches that are more or less suited to handle the respective situation (e.g., 'I conduct an author search for "Heckhausen" and limit my search to the publication year of 1964.'). With regard to the 2015 Association of College & Research Libraries framework (and specifically the "*searching as strategic exploration*" concept), including no less than four response options per item partly accounts for the contextualized nature of information-seeking, and that "experts select from various search strategies, depending on the sources, scope, and context of the information need" (p. 9).

Subjects are required to rate all four response alternatives on 5-point Likert-Scales (*not useful at all* to *very useful*) with respect to their appropriateness of handling the situation. Individual scores are obtained through a standardized scoring key which is based on expert rankings of the appropriateness of the response options. Even though Rosman et al. (2015a) found test reliabilities (Cronbach's Alpha) of $\alpha = .75$ respectively $\alpha = .72$ in two separate studies, scale reliability in the present study was low with an internal consistency (Cronbach's Alpha) of $\alpha = .50$ for t1, $\alpha = .46$ for t2, $\alpha = .38$ for t3, and $\alpha = .57$ for t4. These reliability differences might be accounted for by differences in sample homogeneity across the studies. In fact, both studies by Rosman et al. (2015a) included undergraduate (Bachelor) and graduate (Master) students from all semesters, whereas the present sample was much more homogeneous and only investigated one particular cohort of undergraduates. Since Cronbach's Alpha coefficient is driven by variance and more homogeneous samples often imply reduced variance (Helms, Henze, Sass, & Mifsud, 2006; Onwuegbuzie & Daniel, 2002; Thompson, 2003), the lower internal consistency in our study is not surprising. Helms et al. (2006) even argue that a lower internal consistency of a scale being employed in a homogeneous sample reflects that the scale functions as it should.

As suggested by Wilhelm, Hildebrandt, and Oberauer (2013), *working memory capacity* was measured by a heterogeneous set of three tasks including a complex-span task, an updating task, and a binding task, at the second wave. As information-seeking has a strong verbal component, only tasks with verbal contents were employed. *Complex span* was measured with the tasks by Kane, Hambrick, Tuholski, Wilhelm, Payne, and Engle (2004). Subjects were presented with combinations of sentences and single letters (12 trials; 2 to 5 combinations per trial). Immediately after their presentation, the sentences had to be evaluated as being meaningful or not (e.g., "The police stopped Andreas because he crossed the sky at red light." requires a "no" response). In addition, the letters had to be recalled at the end of each trial. For the *updating* task, materials from Miyake, Friedman, Emerson, Witzki,

Howerter, and Wager (2000) were used. Subjects were presented words from two to five semantic categories and were required to recall, at the end of the respective trial, the last word from each category (12 trials; 9 to 21 words per trial; 2 to 5 semantic categories per trial). *Binding* was measured with the word-number binding tasks included in the study of Wilhelm et al. (2013). In these tasks, participants had to remember several combinations of nouns and two-digit numbers (13 trials, 2 to 6 combinations per trial). All tasks were administered via Inquisit[TM] software. Two additional unscored practice trials were administered prior to each of the three tasks. For all task types, scoring is based on the correctness ("accuracy") of the responses. As Wilhelm et al. (2013) argue that the three task types reflect a broad general working memory capacity factor, scores were aggregated by calculating the arithmetic mean of all three task scores. Test reliability was good with an internal consistency (Cronbach's Alpha) of $\alpha = .89$.

Several *control variables* known to influence information-seeking were included. *Fluid intelligence* has been shown to relate positively to working memory as well as to information-seeking knowledge (Rosman, Mayer, & Krampen, 2015b) and learning (Mayer, 2011). For these reasons, test scores on Raven's Advanced Progressive Matrices (Raven, Raven, & Court, 1998) were included as a control variable. The test – administered at the first wave – consists of 32 visual patterns with missing pieces, and subjects are invited to complete this pattern by choosing the correct piece from eight alternatives. A time limit of 20 minutes was imposed on the test (Hamel & Schmittmann, 2006). Internal consistency (Cronbach's Alpha) in the present sample was $\alpha = .68$.

Information literacy self-efficacy might also – for example through increased effort and persistency while searching – positively influence information-seeking knowledge development (Behm, 2015; Kurbanoglu, Akkoyunlu, & Umay, 2006). Therefore, the information literacy self-efficacy scale by Behm (2015) was administered at the first wave.

The scale consists of 16 self-report items such as "When searching for information on a specific subject, I am able to use different sources of information in a way to obtain a maximum of relevant information". All items were to be rated on a 5-point Likert-Scale. Scale reliability was good with an internal consistency (Cronbach's Alpha) of $\alpha = .89$.

Finally, *epistemic beliefs* (cognitions about the nature of knowledge and knowing in a certain domain; Hofer & Pintrich, 1997) have been shown to moderate information literacy instruction efficacy (Rosman, Peter, Mayer, & Krampen, 2016): Students who conceive psychological knowledge as either an accumulation of absolute "facts" (high absolute beliefs) or as purely subjective "opinions" (high multiplicistic beliefs) will likely not recognize the value of differentiated information searches and of information literacy instruction. Epistemic beliefs might thus also influence the development of information-seeking knowledge. For this reason, the epistemic beliefs questionnaire by Peter, Rosman, Mayer, Leichner, and Krampen (2015) was administered at the first wave. Students were asked to indicate their agreement to 12 absolute and 11 multiplicistic epistemic statements on 5-point Likert scales. For example, agreement to "In this subject, only uncertainty appears to be certain." indicates multiplicism. Absolute and multiplicistic beliefs are conceived as separate scales (Peter et al., 2015). For the absolutism scale, reliability analyses revealed an internal consistency (Cronbach's Alpha) of $\alpha = .69$; for multiplicism, Cronbach's Alpha reached $\alpha = .72$.

3   Results

3.1 Preliminary analyses and variable coding

In a first step, PIKE-P scores were obtained through the standardized scoring syntax by Rosman et al. (2015a). Thereafter, to enhance interpretability of results, these scores were recoded into percentage values by dividing them through the highest attainable score (88) and

subsequently multiplying them with 100. As can be seen in Figure 1, a rather strong increase[5] in information-seeking knowledge occurred over the course of the study.
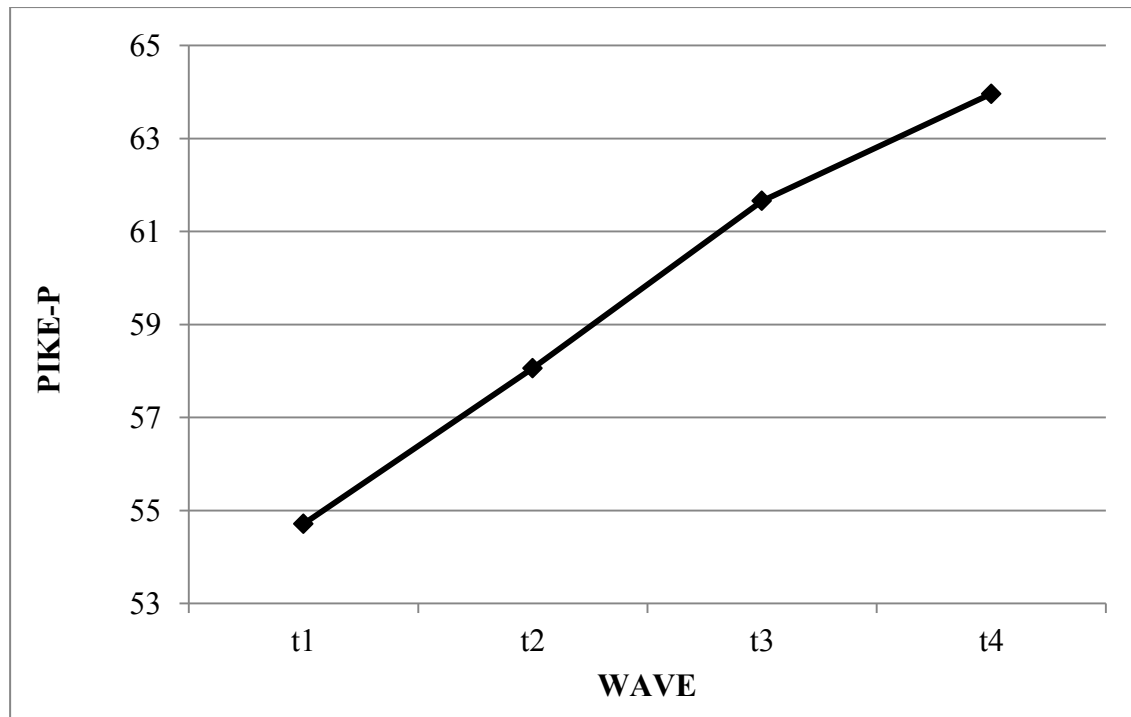

Figure 1. Change in information-seeking knowledge (PIKE-P) throughout the study (N_{t1} = 137; N_{t2} = 126; N_{t3} = 116; N_{t4} = 115).

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[5] As identical test items were used in all four waves, one might ascribe this increase to the repeated administration of the PIKE-P (a so-called *testing effect*). To investigate this, data from a cross-sectional study conducted at another German university were used (see Rosman, Mayer, & Krampen, 2015c). Among others, n = 27 first semester students and n = 18 third semester students participated in the study. Both samples were comparable with regard to age, gender distribution, and testing period (beginning of semester). For first semester students, PIKE-P scores were almost identical across both studies (cross-sectional study: M = 54.18; SD = 9.74; longitudinal study: M = 54.71; SD = 8.41). Third semester students from the cross-sectional study had even higher (M = 63.76; SD = 12.49) scores than third semester students from the longitudinal study (M = 61.66; SD = 7.48). Since the presence of a testing effect would imply the contrary, this speaks against such an interpretation.

Concerning information literacy instruction, it was found that only 15 students (13 %) had participated in library instruction during the study period. Moreover, descriptive analyses of the curriculum-embedded instruction items revealed all three of them to be strongly skewed to the right, indicating that students had only received rather little curriculum-embedded information literacy instruction in the three respective topics (reference databases, academic search engines, and citation skills). Since calculating arithmetic means on strongly skewed items might be problematic both for descriptive interpretation and for inferential statistics (Cohen, 2008), a discrete variable with three categories was formed: Participants who had not received curriculum-embedded instruction in any of the three topics were assigned[6] the value 0 ($n = 18$). Participants who had received, in total, less or equal than three hours of curriculum-embedded instruction were assigned the value 1 ($n = 45$). Finally, participants who had received more than three hours of curriculum-embedded instruction were assigned the value 2 ($n = 52$). One case could not be assigned to a group due to missing data.

Table 1 shows means, standard deviations, and correlations of all study variables. A low and marginally significant positive Spearman correlation between CE_INST and PIKE-P was found for the third and fourth wave (see Table 1). No correlations between LIB_INST and PIKE-P were found for any of the four waves. With regard to working memory capacity, marginally to highly significant correlations between WMC and PIKE-P were found for all waves except the baseline measure.

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[6] The rationale for choosing three categories was as follows: First, including a group that had received no instruction at all allows an easier interpretation of the subsequent multilevel analyses (since it permits to estimate the growth of information-seeking knowledge that is independent of instruction). Including one group that had only received rather little instruction and another one that had received a bit more also facilitates interpretation of results.

Table 1

Means, standard deviations, and correlations of all study variables

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11
1 LIB_INST	-	-	-										
2 CE_INST	-	-	.21*	-									
3 PIKE-P (t1)	54.71	8.41	-.04	.07	-								
4 PIKE-P (t2)	58.06	8.12	.11	.04	.42***	-							
5 PIKE-P (t3)	61.66	7.48	-.01	.08	.38***	.56***	-						
6 PIKE-P (t4)	63.96	8.83	.13	.17$^+$	.39***	.52***	.60***	-					
7 WMC	0.71	0.10	.15	-.01	-.02	.23**	.18$^+$	.32***	-				
8 APM	21.01	3.72	.13	-.07	.11	.19*	.11	.18$^+$	.40***	-			
9 SES-IB-16	3.35	0.52	.04	.03	.12	.05	-.09	.06	-.01	-.01	-		
10 EBI-AM-ABS	2.11	0.46	-.06	-.01	-.10	-.13	-.14	-.19*	.13	.13	.20*	-	
11 EBI-AM-MULT	3.43	0.53	-.11	.05	-.12	-.01	-.06	-.02	.13	-.03	-.12	-.13	-

Note. N_{t1} = 137; N_{t2} = 126; N_{t3} = 116; N_{t4} = 115; *M* = arithmetic mean; *SD* = standard deviation; LIB_INST = participation in a library instruction course (discrete); CE_INST = curriculum-embedded information literacy instruction (discrete); PIKE-P = information-seeking knowledge; t1-t4 = waves; APM = Raven's Advance Progressive Matrices; SES-IB-16 = information literacy self-efficacy; EBI-AM-ABS = absolute epistemic beliefs; EBI-AM-MULT = multiplicistic epistemic beliefs; WMC = working memory; no means calculated for LIB_INST and CE_INST because of their discrete nature; all correlations including discrete variables are Spearman correlations, all other correlations are Pearson correlations.

$^+$ *p* < .10.

* *p* < .05.

** *p* < .01.

*** *p* < .001.

3.2 Multi-level analyses

All three hypotheses were tested by linear multi-level modeling using the SPSS™ 20 MIXED procedure. As the highest-valued levels of fixed factors can be seen as "reference categories" in SPSS™ MIXED (West, Welch, & Galecki, 2014), both the LIB_INST and the CE_INST variables were recoded so that higher values indicate *less* information literacy instruction (i.e., scale values of 2 on the LIB_INST_R respectively 3 on the CE_INST_R variable indicates that no instruction had happened at all). Since the first hypothesis addresses the growth of information literacy that is *independent* of information literacy instruction, this allows an easier interpretation of results (West et al., 2014). Moreover, the working memory capacity variable (WMC) was z-standardized ($M = 0.00$; $SD = 1.00$), again to simplify the interpretation of results. Finally, a time variable (WAVE) indicating the four measurement points and ranging from 0 to 3 (0 being the baseline measurement) was created.

Maximum Likelihood (ML) was used to estimate all models. No explicit covariance structure was assumed ("unstructured" covariance structure). An unconditional mean model (Model 1) was first calculated to examine time-independent individual variations in PIKE-P scores (see Table 2). Only the intercept was included in the model, both as fixed and as random factor. To examine the amount of total outcome variance related to interindividual differences, an intraclass correlation coefficient (ICC) was calculated by dividing the intercept variance (τ_{00}) through the sum of intercept (τ_{00}) and residual variance (σ^2). An ICC of 27.49 / (27.49 + 52.64) = .34 reveals that 34 percent of the variation in PIKE-P scores is due to individual differences. An ICC over .25 suggests that multi-level modeling may perform better than more traditional methods (e.g., repeated measures analyses of variance), thus justifying our decision to use multi-level modeling (Shek & Ma, 2011).

Table 2

Fixed effects, covariance parameters, and fit indices of all five multi-level models

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
Fixed effects					
Intercept	59.24^{***} (0.56)	54.86^{***} (0.65)	57.76^{***} (1.70)	55.00^{***} (0.66)	58.11^{***} (1.65)
WAVE	-	3.20^{***} (0.28)	1.78^{**} (0.68)	3.18^{***} (0.27)	1.93^{**} (0.67)
CE_INST_R=1 (> 3 hours)	-	-	-2.53 (2.00)	-	-2.06 (1.93)
CE_INST_R=2 (< 3 hours)	-	-	-4.72^{*} (2.00)	-	-4.88^{*} (1.94)
CE_INST_R=3 (no instruction)	-	-	0.00 (0.00)	-	0.00 (0.00)
LIB_INST_R=1 (yes)	-	-	-1.37 (2.05)	-	-2.67 (2.00)
LIB_INST_R=2 (no)	-	-	0.00 (0.00)	-	0.00 (0.00)
APM	-	-	-	-	0.83 (0.73)
SES-IB-16	-	-	-	-	0.78 (0.68)
EBI-AM-ABS	-	-	-	-	-1.09 (0.69)
EBI-AM-MULT	-	-	-	-	-1.05 (0.68)
WMC	-	-	-	0.20 (0.66)	0.52 (0.74)
WAVE*CE_INST_R=1 (> 3 hours)	-	-	1.76^{*} (0.80)	-	1.58^{*} (0.79)
WAVE*CE_INST_R=2 (< 3 hours)	-	-	1.59^{*} (0.80)	-	1.40^{+} (0.80)
WAVE*CE_INST_R=3 (0 hours)	-	-	0.00 (0.00)	-	0.00 (0.00)
WAVE*LIB_INST_R=1 (yes)	-	-	0.93 (0.82)	-	0.76 (0.82)
WAVE*LIB_INST_R=2 (no)	-	-	0.00 (0.00)	-	0.00 (0.00)
WAVE*RAVEN	-	-	-	-	-0.17 (0.30)
WAVE*SES-IB-16	-	-	-	-	0.00 (0.28)
WAVE*EBI-AM-ABS	-	-	-	-	-0.27 (0.28)
WAVE*EBI-AM-MULT	-	-	-	-	0.15 (0.28)
WAVE*WMC	-	-	-	0.85^{**} (0.27)	0.70^{*} (0.30)
Covariance parameters					
σ^2	52.64 (3.93)	30.46 (2.82)	29.70 (2.80)	29.44 (2.73)	28.82 (2.74)
τ_{00}	27.49 (5.31)	34.98 (7.25)	30.81 (7.18)	33.51 (7.15)	26.47 (6.55)
τ_{11}	-	3.14 (1.38)	2.30 (1.23)	2.83 (1.31)	2.08 (1.19)
Fit Indices					

-2LL	3493.76	3345.31	3031.07	3202.57	2950.23
AIC	3497.76	3353.31	3055.07	3218.57	2994.23
BIC	3506.15	3370.10	3104.41	3251.89	3084.34

Note. Dependent variable = information-seeking knowledge (PIKE-P); WAVE = slope; CE_INST_R = curriculum-embedded information literacy instruction (discrete, recoded);

LIB_INST_R = participation in a library instruction course (discrete, recoded); Higher values on CE_INST_R and LIB_INST_R indicate less instruction; APM = Raven's Advance

Progressive Matrices (z-standardized); SES-IB-16 = information literacy self-efficacy (z-standardized); EBI-AM-ABS = absolute epistemic beliefs (z-standardized); EBI-AM-MULT

= multiplicistic epistemic beliefs (z-standardized); WMC = working memory (z-standardized); σ^2 = residual variance; τ_{00} = intercept variance; τ_{11} = slope variance; -2LL = -2 * log-

likelihood; AIC = Akaike's Information Criterion; BIC = Bayesian Information Criterion; Model 1 = unconditional mean model; Model 2 = unconditional linear growth curve model;

Model 3 = linear growth curve model including CE_INST_R and LIB_INST_R; Model 4 = linear growth curve model including WMC; Model 5 = linear growth curve model

including WMC, CE_INST_R, LIB_INST_R, and control variables; Elements in parentheses = standard deviations.

$^+ p < .10.$

$^* p < .05.$

$^{**} p < .01.$

$^{***} p < .001.$

In a second step, individual variations of PIKE-P growth rates were analyzed in an unconditional linear growth curve model (Model 2). The variable WAVE was added to Model 1 as both a fixed effects and a random effects variable. PIKE-P levels of the first wave were estimated at $\beta = 54.86$ ($SD = 0.65$); the fixed effect estimate of WAVE indicates that with each wave, mean PIKE-P scores increase by $\beta = 3.20$ ($SD = 0.28$; $p < .001$; see Table 2). As the estimate of WAVE significantly differed from 0, further model testing (i.e., by adding covariates) was justified (Shek & Ma, 2011). With the increase in PIKE-P scores over the study period being clearly linear (see Figure 1), no models with cubic or quadratic terms were calculated.

With regard to Hypothesis 1, Model 2 shows that information-seeking knowledge indeed increases throughout the first three semesters of undergraduate psychology studies. To investigate to what extent information literacy instruction accounts for this increase, another model (Model 3) was specified which included – as fixed-effects factors – both the categorical (and reverse-coded; see above) CE_INST_R and LIB_INST_R variables as well as their interaction terms with WAVE (WAVE*LIB_INST_R and WAVE*CE_INST_R, respectively). Even with both instruction variables in the model, the estimate of WAVE remained significant ($\beta = 1.78$; $p < .01$). As the highest values of LIB_INST_R and CE_INST_R represent groups that did *not* undergo information literacy instruction (the so-called "reference categories"; see above), the beta weight of WAVE can be interpreted as the amount of information-seeking knowledge gains that happen *independent* of instruction (West et al., 2014). Our data thus show that students who underwent no information literacy instruction at all nevertheless had an increase [7]of $\beta = 1.78$ ($SD = 0.68$) in PIKE-P scores per wave (i.e., per semester). Hypothesis 1 is supported.

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[7] An unexpected additional finding was a significant main effect of CE_INST_R for the group that had undergone less than three hours of instruction ($\beta = -4.72$; $SD = 2.00$; $p < .05$): Students who had

The significant estimates of WAVE*CE_INST_R indicate that students who underwent curriculum-embedded instruction had steeper PIKE-P growth rates than students who did not. As can be derived from the beta values in Table 2, the increase in PIKE-P scores in the group who had received less than three hours of instruction was nearly two times higher than the respective increase of students who did not receive any instruction ($1.78 + 1.59 = 3.37$; thus an increase of 89 percent). With regard to the group who had received more than three hours of instruction, the respective increase was even higher with 99 percent ($1.78 + 1.76 = 3.54$). Finally, no significant effects of library instruction (LIB_INST_R) on PIKE-P growth rates were found. In sum, with both instruction variables in the model, only curriculum-embedded instruction had an effect on PIKE-P growth rates. Accordingly, Hypothesis 2 is supported.

Compared to Model 2, variance in slopes decreased from $\tau_{11} = 3.14$ to $\tau_{11} = 2.30$, thus suggesting that the inclusion of the instruction variables into the model explained 27 percent of variance in growth rates. In sum, our results suggest that information literacy instruction indeed has a considerable effect on students' learning curves. Nevertheless, they also show that a significant proportion of growth in PIKE-P scores is not accounted for by information literacy instruction, thus suggesting that other factors (i.e., self-regulated learning) might also influence the development of information-seeking knowledge. With regard to the first two hypotheses, our data thus indicate that psychology students develop more proficient information-seeking knowledge over the first half of their undergraduate studies, even when no formalized instruction takes place. Still, especially curriculum-embedded information literacy instruction seems to constitute a very central factor that may facilitate learning of information-seeking knowledge.

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undergone less than three hours of curriculum-embedded instruction had significantly lower PIKE-P scores at baseline (t1) than students who had not undergone any instruction at all. As students were randomly assigned to their respective observational methods course, this is likely caused by chance.

To test Hypothesis 3, z-standardized WMC was introduced – again as a fixed effects variable – into the unconditional linear growth curve model (Model 2). The main effect of WMC in the resulting model (Model 4) suggests that PIKE-P does not relate to WMC at baseline (β = 0.20; SD = 0.66; p = ns). The significant interaction of WAVE and WMC (see Figure 2) nevertheless shows that PIKE-P scores of students with a given WMC will each semester increase by an additional 27 percent compared to students with a WMC one standard deviation (1 SD) below (3.18 + 0.85 = 4.03; see Table 2). Compared to Model 2, variance in slopes decreased from τ_{11} = 3.14 to τ_{11} = 2.83, thus suggesting that the inclusion of WMC into Model 2 explained 10 percent of additional variance in growth rates. Accordingly, Hypothesis 3 is confirmed: The higher psychology students' WMC, the higher their increase in information-seeking knowledge over the first half of their undergraduate studies.
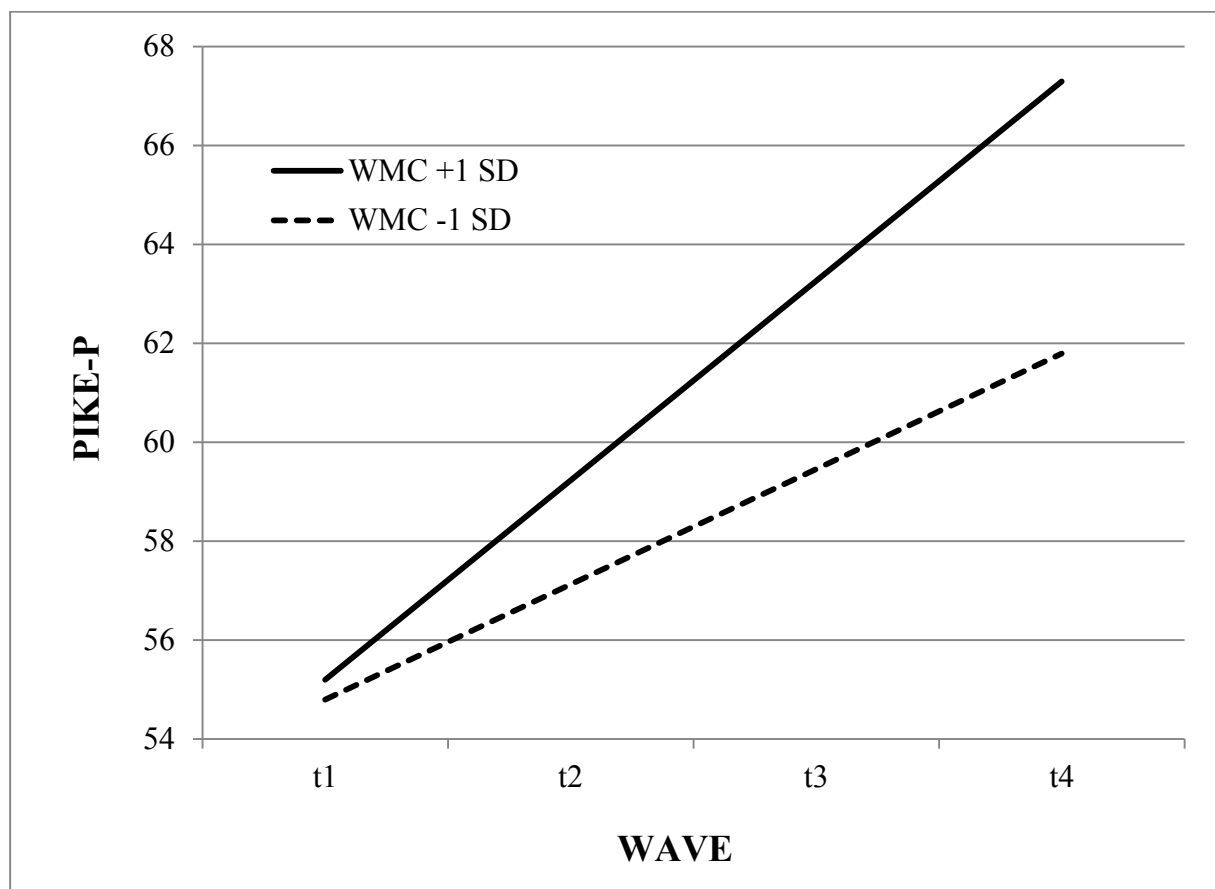

Figure 2. Estimated change in information-seeking knowledge (PIKE-P) as a function of working memory capacity (WMC).

To investigate whether confounding variables were responsible for the longitudinal effects of WMC, a model including all study variables (Model 5) was specified (see Table 2). Results on this model show that WMC remains a significant predictor of information-seeking knowledge growth when controlling for the effects of information literacy instruction, fluid intelligence, information literacy self-efficacy, and epistemic beliefs.

4 Discussion

The present study investigated the development of information-seeking knowledge in psychology undergraduates over the first half of their undergraduate studies. A four-wave longitudinal study with $N = 137$ students (first wave) was conducted. Dropout occurred unsystematically and was rather small with only 16 percent from the first to the last wave. Descriptively, a linear increase in information-seeking knowledge was found, which, according to additional analyses of cross-sectional data from another study, cannot be explained by testing effects. Multi-level modeling revealed this increase to be considerably smaller but to remain significant when controlling for the effects of library and curriculum-embedded information literacy instruction. With regard to situational factors, curriculum-embedded information literacy instruction was shown to significantly influence the development of information-seeking knowledge, whereas no significant effects were found for library instruction. Concerning individual factors and in line with cognitive load theory, working memory capacity was shown to moderate the development of information-seeking knowledge: Students with high working memory capacity had a steeper increase than students with lower working memory capacity.

4.1 Longitudinal development of information-seeking knowledge

With regard to the first hypothesis, our data show that psychology students' information-seeking knowledge significantly increases over the first half of their undergraduate studies, and that up to a certain extent, this increase is independent of information literacy instruction. Unstructured, self-regulated learning of information-seeking skills might thus be well-suited to acquire at least some simpler information-seeking strategies. Nevertheless, especially since our findings on Hypothesis 2 indicate that undergraduates benefit hugely from information literacy instruction, it is susceptible that outside of formal instruction, students acquire a rather basic, unstructured, and fragmented knowledge base (Head & Eisenberg, 2009; Peter, Leichner, Mayer, & Krampen, 2015). For example, they might stick to simpler search tools like Google Scholar[TM] and even neglect their advanced functions (e.g., limit options). Previous research indicating that many students employ "conservative" information-seeking strategies (Warwick et al., 2009) substantiates this assumption.

Concerning Hypothesis 2, a significant relationship between curriculum-embedded information literacy instruction and information-seeking knowledge was found for the third and fourth wave, which – regarding the fact that the instructional courses took place in the first two semesters – is not surprising. Multi-level modeling revealed that students who had participated in curriculum-embedded information literacy instruction during their first two semesters had considerably steeper learning curves than non-participants. In sum, these results suggest that even though undergraduates seem to acquire at least some search strategies on their own, even rather small amounts of curriculum-embedded instruction have a substantial effect on the elaboration of these strategies (see also Head & Eisenberg, 2009). Regrettably, curriculum-embedded forms of information literacy instruction are still relatively rare (Derakhshan & Singh, 2011; Probert, 2009; Schmidt-Hertha & Rott, 2014).

With regard to library instruction, multi-level modeling revealed no significant effect of library instruction on the development of information-seeking knowledge. Apart from the obvious methodological explanation (i.e., too few instruction participants), this might be caused by the fact that library instruction sessions are often rather short (at most 90 minutes) as well as generic and not tailored to information-seeking in a specific domain. With information-seeking significantly differing throughout disciplines (Association of College & Research Libraries, 2010; Rosman & Birke, 2015), one might therefore argue that library instruction is not that well-suited to improve discipline-specific search strategies.

4.2   Relations with working memory capacity

Cognitive load theory predicts that an overloaded working memory impairs the transfer of learning content to long-term memory. Accordingly, we expected working memory capacity to influence the development of information-seeking knowledge (Hypothesis 3). In fact, acquiring information-seeking skills requires considerable amounts of working memory capacity, especially when elaborate procedures (e.g., bibliographic database searching) are taught with rather complex instructional methods. Our findings support this expectation and indicate that over the first half of psychology students' undergraduate studies, the steepness of information-seeking knowledge gains varies as a function of working memory capacity: Students with higher working memory capacity have steeper learning curves than their peers with lower capacity. Compared to information literacy instruction, the amount of slope variance explained by working memory capacity was smaller (even though, with approximately 10 percent, nevertheless substantial). In sum, we conclude that working memory capacity surely is important for the development of information-seeking knowledge, but that information literacy instruction might even play a more central role.

Additional analyses revealed that working memory capacity remained a significant predictor of information-seeking knowledge development when controlling for the effects of

information literacy instruction (and several other variables). This underlines the importance of working memory capacity in acquiring information-seeking skills outside of formal instruction. In fact, self-regulated learning of information-seeking skills not only requires students to manage their learning (e.g., to memorize their experiences with diverse information-seeking strategies), but also to manage the information-seeking process as such, which by all means induces substantial amounts of cognitive load.

4.3   Limitations and practical implications

A major strength of our study lies in its longitudinal design. This does not only allow to investigate how information-seeking knowledge develops without explicit instruction, but also provides some support for causal effects of curriculum-embedded instruction and working memory on the development of information-seeking knowledge. Nevertheless, Wilkinson (1999) issues a note of caution in this respect by arguing that causality may only be demonstrated in experimental designs. Even though some control variables were added to our calculations, it is in fact entirely possible that unmeasured third variables (e.g., attentional or anxiety disorders) might be responsible for the longitudinal effects of, for example, working memory, and not the variable itself.

A second limitation is the low reliability of our dependent variable. Two reasons likely account for this: First, Rosman et al. (2015a) argue that high reliability estimates might prove difficult to achieve due to the breadth and heterogeneity of the concept of information-seeking knowledge. Second, the homogeneity of our sample (one cohort of psychology freshmen) might have further impaired reliability (Thompson, 2003). We nevertheless also point out that the correlations between the measurement points (which is a very conservative indicator of test-retest reliability since we *expected* students to differ interindividually in their information-seeking knowledge gains throughout the study) remain rather high with $r = .42$ to $r = .60$ (see Table 1).

As a third limitation, we concede that, since our participants received very little information literacy instruction and our sample size was restricted, the respective conclusions might be less robust than expected. Especially the non-significant effects of library instruction might be accounted for by reduced statistical power. Type I errors are also possible, which is why further research should strive to replicate our findings, for example using latent growth curve modeling. We also have to point out that the data on information literacy instruction were collected with self-report measures and that the recoding of the curriculum-embedded instruction variable to a dichotomous format – albeit necessary due to item skewness – was based on pragmatic grounds. Furthermore, our data do not allow investigating specific educational practices employed within the respective instructional modules, and no conclusions can be drawn about the type of search tools students used throughout the study period. We concede that this is a significant limitation concerning our findings on the effects of information literacy instruction (but not regarding our findings on cognitive load). Experimental designs with randomized assignment of subjects to specific instructional conditions surely are better suited to contrast different types of instruction. However, they are difficult to realize in longitudinal field studies, especially when striving to investigate how information-seeking knowledge develops *independently* of information literacy instruction.

Finally, our study used a rather specific sample and one could question whether our findings might be transferrable to other domains. In fact, the importance of information-seeking may vary across domains and therefore, curriculum-embedded instruction might play a smaller role in domains like, for example, computer science (Rosman & Birke, 2015). Clearly, further longitudinal studies including students from diverse domains are necessary, as are longitudinal investigations on the development of information-seeking knowledge in the second half of students' undergraduate studies or in their Master studies.

With regard to practical implications, we conclude that even short instructional sessions may very well help students develop more elaborate information-seeking knowledge. In line with this, Sheesley (2002) argues that "not everything about using a library and its resources reveals its secrets through trial and error" (p. 39). This is good news for policymakers and librarians alike, as it shows that even rather small amounts of curriculum-embedded instruction (i.e., three hours or even less) can make a significant difference. Moreover, as our data suggests that both formalized instruction and self-regulated learning of information-seeking skills seem beneficial, we fully agree with Herther (2008) who pleads for an integration of these two forms of learning. For example, one might seek to actively support students during their self-regulated learning process by providing adequate tutorials, giving advice, providing formative feedback, or simply by answering questions (Herther, 2008). Blended learning courses (i.e., that include online materials and classroom sessions) might be especially promising in this regard (e.g., Mayer, Peter, Leichner, & Krampen, 2015).

As emphasized by cognitive load theory, it is nevertheless crucial that information literacy instruction and tutorials do not overload students' working memory. Since it is not possible to reduce the amount of intrinsic cognitive load related to information-seeking, practitioners should strive to reduce extraneous cognitive load to avoid the double burden students often face when acquiring information-seeking skills (i.e., complex learning contents and complex learning environment).

In their Four-Component Instructional Design model (4C/ID-model), van Merriënboer and Kirschner (2013) suggest four interrelated components of good environments for complex learning. These can easily be adapted to information-seeking. First, the model emphasizes the importance of a so-called *whole-task approach* to learning: Learning tasks should consist of meaningful whole-task experiences that are based on real-life tasks (van Merriënboer & Kester, 2014) and that are organized in a simple-to-complex manner (van Merriënboer &

Kirschner, 2013). Good information literacy instruction should thus draw on tasks with gradually increasing complexity that reflect real-world information searches and that are related to the domain students engage in. Moreover, the 4C/ID-model stresses that *supportive information* (information describing how a certain task domain is organized and how problems in it can be approached) should be presented before learners start working on actual learning tasks, and that *procedural information* (information that is directly necessary to perform routine aspects of the learning tasks) should be presented to the learners exactly when needed (i.e., while performing the tasks; van Merriënboer & Kester, 2014; van Merriënboer & Kirschner, 2013). Finally, the model emphasized that routine aspects of the task that require a high level of automatization should be intensively practiced (so-called *part-task practice*; van Merriënboer & Kirschner, 2013). According to the 4C/ID-model, instruction that is designed based on these principles is best suited to reduce cognitive load. During instruction, intrinsic cognitive load might be reduced by a simple-to-complex organization of the learning tasks. Extraneous cognitive load, in contrast, can be reduced by a high amount of support and guidance, especially during the first practical experiences with the learning tasks (van Merriënboer & Kirschner, 2013). Detailed instruction on how to design information literacy instruction for social sciences students, with the 4C/ID-model as a basis, can be found in Wopereis, Frerejean, and Brand-Gruwel (2015).

Perhaps the most significant advantage of curriculum-embedded instruction over generic library instruction is – in terms of the 4C/ID-model – that students work on authentic and discipline-specific search tasks (a so-called whole-task approach; van Merriënboer & Kirschner, 2013). Nevertheless, it also has to be pointed out that both types of instruction can be designed either well or poorly regarding all four model components, and that this can hugely impact cognitive load. Since we were not able to collect specific data on how the two instruction types were designed in terms of the 4C/ID-model, further – preferably

experimental – research should strive towards more differentiated investigations of the effects of different instruction types on the development of information-seeking knowledge.

Moreover, again with regard to our findings on working memory capacity, search tool usability plays a crucial role. Especially outside of formal instruction, acquiring information-seeking skills implies the double burden of having to manage both the learning process (e.g., extrapolating different search strategies, evaluating their value, memorizing them, etc.) and the information-seeking process as such. As both these processes generate cognitive load, we expect that simplifying the information-seeking process (e.g., through reducing database complexity) will free up cognitive resources for the (now even simpler) learning process. We therefore see bibliographic database vendors in the obligation to dedicate their full efforts to enhancing the usability of their interfaces. This is especially important since previous research has shown that todays' database interfaces overtax a great number of students (Rosman, Mayer, & Krampen, 2016). Enhancing navigability (Green & Pearson, 2011), providing query previews (e.g., Tanin, Lotem, Haddadin, Shneiderman, Plaisant, & Slaughter, 2000), reducing library terminology (e.g., Kupersmith, 2012), and implementing error prevention features (Manzari & Trinidad-Christensen, 2013), just to name a few, are valuable techniques in this respect. Kalyuga (2010) as well as Shneiderman and Plaisant (2010) provide excellent overviews on how to design simple yet efficient multimedia interfaces.

When simplifying databases, one nevertheless has to bear in mind that a reduction of complexity might also impair search precision and efficiency, especially for more advanced users (Google Scholar^{TM} being a pertinent example in this respect). Along with moderately simplifying databases, we therefore advocate a need for concentrated teaching of more complex database features, thus serving as another means to reduce cognitive load in challenging search situations.

4.4   Conclusions

In conclusion, our study shows that both instruction and working memory capacity are essential for the development of information literacy. Intensifying information literacy instruction is therefore crucial when striving to foster students' information-seeking skills. Instructional sessions should be tailored to the domain students engage in and ideally be embedded into the curriculum. When no formal instruction is provided, most students are nevertheless capable of acquiring at least some information-seeking knowledge through self-regulated learning, given that they possess a sufficiently high working memory capacity. Especially for students with moderate to low working memory capacity, reducing cognitive load is essential. This can be achieved by keeping online tutorials and instructional modules as simple as possible and by enhancing the usability of search tools (e.g., bibliographic databases). We acknowledge that this requires substantial effort from database vendors, librarians, lecturers, curriculum designers, and policymakers alike, but considering the crucial role of information literacy in today's information society, we expect it to be worth the trouble.

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