MASTER'S THESIS

Smarter with Smartphones

The Influence of Device Type on Search Query Length, Search Query Specificity and Number of Search Queries

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Smarter with Smartphones: The Influence of Device Type and Task Type on Search Query Length, Search Query Specificity and Number of Search Queries

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Nederlandse samenvatting

Tegenwoordig gebruiken bijna alle adolescenten mobiele telefoons. Op school gebruiken leerlingen hun smartphones om met behulp van het internet informatietaken op te lossen. Leren door te zoeken op internet is de afgelopen decennia onderwerp geweest van wetenschappelijk onderzoek en dit onderzoek resulteerde in het Information Problem Solving while using the Internet model (IPS-I-model) (Brand-Gruwel, Wopereis, & Walraven, 2009). Het succes van zoekopdrachten wordt onder andere beïnvloed door de lengte en specificiteit van zoektermen. Het aantal gebruikte zoekopdrachten geeft aan hoe snel een probleem is opgelost. Hoewel er veel wetenschappelijk onderzoek is gedaan naar leren door op internet te zoeken, werd in de meeste onderzoeken gebruik gemaakt van computers. Er is weinig vergelijkend onderzoek gedaan naar zoekgedrag op computers en smartphones.
Het doel van dit onderzoek was het bepalen van het effect van het type apparaat en het type taak op het zoekgedrag van middelbare scholieren.

Een experiment met een mixed design is uitgevoerd, met zowel een between-subjects variabele (apparaat), als een within-subjects variabele (taaktype). Achtenveertig leerlingen uit de derde en vierde klas van het havo en het vwo van een grote Nederlandse scholengemeenschap hebben deelgenomen aan dit onderzoek. Drieëntwintig leerlingen gebruikten een laptop en 25 leerlingen gebruikten een smartphone om een feitelijke zoektaak en een complexe informatietaak op te lossen.

Om de zoektermen vast te leggen, is gebruik gemaakt van schermopnames. Studenten moesten hun antwoord op de feitelijke zoektaak en een essay over de informatietaak opschrijven op een antwoordblad.

Type taak had een significant effect op de lengte van zoektermen, terwijl type apparaat geen effect had. Verder werd geen significant interactie-effect op lengte van zoektermen gevonden. Hoewel de lengte van zoektermen niet significant verschilde bij herformuleren bij verschillende taaktypes, werd wel significant verschillend gedrag gevonden tijdens herformuleren. Er werd vaker gebruik gemaakt van nieuwe zoektermen, in plaats van aanpassingen van zoektermen, bij complexe taken, dan bij feitelijke taken. Type taak had ook een significant effect op de specificiteit van zoektermen. Het type apparaat had geen significant effect op specificiteit en er werd geen significant interactie-effect gevonden. Specificiteit verschilde niet significant bij het herformuleren. Dit wijst erop dat er een alternerend patroon tussen specialisatie en generalisatie plaatsvond bij beide taaktypes op beide apparaten. Er werd een significant interactie-effect van type apparaat en taaktype op het aantal zoektermen gevonden. Daar waar het aantal zoekopdrachten vergelijkbaar was in feitelijke zoektaken op beide apparaten, nam het aantal zoekopdrachten toe op laptops bij het oplossen van complexe taken en af bij smartphones.

Resultaten van dit onderzoek impliceren dat middelbare scholieren zowel laptops als smartphones kunnen gebruiken tijdens het zoeken naar informatie. Alleen bij het oplossen van complexe informatietaken is het raadzaam om laptops te gebruiken in plaats van smartphones. Bovendien voegt deze studie het gebruik van verschillende apparaten toe aan de subcompetentie 'zoeken naar informatie' van het IPS-I-model (Brand-Gruwel et al., 2009). Geconcludeerd kan worden dat het zoeken naar informatie op smartphones en laptops voornamelijk op dezelfde wijze verloopt.

Keywords: IPS-I model, complexe informatietaak, mobiel zoeken, lengte van zoektermen, specificiteit van zoektermen, aantal zoektermen, herformuleren.

Summary

Nowadays almost all adolescents use mobile phones. At school students use their smartphones to search the internet, while solving information-based problems. Learning by searching the web has been subject of scientific research for the past decades and this research resulted in the Information Problem Solving while using the Internet model (IPS-I model) (Brand-Gruwel et al., 2009). Search success is, among other things, influenced by the query length and query specificity. The number of queries used indicates how fast a problem is solved. Although there is ample scientific research into learning by searching the web, participants in most of these studies used a computer. There has not been much comparative research in searching behaviour on computers and smartphones.
The present study aimed to determine the effect of device type and task type on querying behaviour of adolescents in secondary school.

An experiment using a mixed design has been conducted, including both a between-subjects variable (device) and a within-subjects variable (task type). Forty-eight students from the 11th and 12th grade of the two highest levels in a large Dutch school for secondary education participated in this study. Twenty-three students used a laptop, and 25 students used a smartphone to solve both a fact-finding task and an information-based problem.

Screen recordings were used to record the different search queries. Students had to formulate an answer to the fact finding task, and write an essay regarding the information-based problem on an answer sheet.

Task type had a significant effect on query length, whereas device type had no significant effect. Moreover, no significant interaction effect on query length has been found. Although query length did not differ significantly during reformulations in different task types, query behaviour differed significantly. New queries, instead of adaptations of the previous query, were used significantly more in information-based problems, than in fact-finding tasks. Task type also had a significant effect on search query specificity. Device type had no significant effect on query specificity, and no significant interaction effect between task type and device type on query specificity has been found. Query specificity did not differ significantly in reformulations, indicating that an alternating pattern of generalization and specialization occurred in both task types and for both device types. A significant interaction effect of device type and task type on number of queries has been found. Whereas the number of search queries was almost equal in fact-finding tasks on both device types, the number of queries needed to solve information-based problems increased for laptop users and decreased for smartphone users.

Results of this study implicate that in secondary education, students could use both laptops and smartphones while searching for information. Only when solving information-based problems, it is advisable to use laptops instead of smartphones. Furthermore, results of this study add to the usage of different devices to the ‘searching for information’ subskill of the IPS-I model (Brand-Gruwel et al., 2009). It could be concluded that searching for information proceeds mainly in the same way on smartphones and laptops.

Keywords: IPS-I model, information-based problem, mobile search, query length, query specificity, number of queries, reformulation

Smarter with Smartphones: The Influence of Device Type and Task Type on Search Query Length, Search Query Specificity and Number of Search Queries

1. Introduction

Mobile phones are an integral part of modern-day society. In 2018 more than 98 percent of adolescents in the Netherlands had access to a smartphone with internet connection (CBS, 2018). Traditionally mobile phones were used in dynamic on-the-go environments (Church & Oliver, 2011; Ito, 2009). However, nowadays smartphones are also increasingly used as a replacement for computers in a stationary setting, e.g., at home, at work or at school (Anshari, Almunawar, Shahrill, Wicaksono, & Huda, 2017; Church & Oliver, 2011; Westlund, Gómez-Barroso, Compañó, & Feijóo, 2011).

In educational settings, adolescents are using their smartphones, among other things, to search the internet for information while solving information-based problems (Anshari et al., 2017; Kammerer, Brand-Gruwel, & Jarodzka, 2018). Information-based problems are problems that require external information, e.g., from the web, in order to be solved. To search for information on the web successfully, students will have to specify the information need, search for information sources, evaluate the information and select relevant information and combine information from different sources (Brand-Gruwel & Stadtler, 2011; Brand-Gruwel, Wopereis, & Vermetten, 2005).

Learning by searching the web has been described in the model of Information Problem Solving while using the Internet (IPS-I model) (Brand-Gruwel et al., 2005; Brand-Gruwel et al., 2009). In this model, information problem solving has been described as a complex cognitive skill, containing several sub-skills students will have to master, in order to solve information-based problems (Brand-Gruwel et al., 2005; Brand-Gruwel et al., 2009; Walhout, Oomen, Jarodzka, & Brand-Gruwel, 2017).

Following the IPS-I model, the first step in interaction with a device, after the definition of the problem, is searching for information. Students will have to formulate search queries in a search engine (e.g., Google), execute the search, analyse and interpret their results on the search engine result page (SERP) and, if the information problem could not be solved, reformulate their search query (Sanchiz, Chevalier, & Amadieu, 2017a; Sharit, Hernández, Czaja, & Pirolli, 2008).

There is ample scientific research regarding the sub-skill ‘searching information’ from the IPS-I model by adolescents and adults, while using the internet on desktops and laptops (e.g., Agapie, Golovchinsky, & Qvarfordt, 2013; Athukorala, Głowacka, Jacucci, Oulasvirta, & Vreeken, 2016; Aula, Khan, & Guan, 2010; Belkin et al., 2003; Brand-Gruwel & Stadtler, 2011; Brand-Gruwel et al., 2009; Dommes, Chevalier, & Lia, 2011; Hu, Lu, & Joo, 2013; Huang & Efthimiadis, 2009; Jansen & Spink, 2006; Jansen, Spink, & Narayan, 2007a; Jansen, Zhang, & Spink, 2007b; Karanam & van Oostendorp, 2016; Liu, Gwizdka, Liu, Xu, & Belkin, 2010; Monchaux, Amadieu, Chevalier, & Mariné, 2015; Sanchiz, Amadieu, Fu, & Chevalier, 2019; Sanchiz et al., 2017a; Sanchiz et al., 2017b; Sharit et al., 2008; Walhout et al., 2017; Walraven, Brand-gruwel, & Boshuizen, 2008; Wildemuth, Kelly, Boettcher, Moore, & Dimitrova, 2018). These studies focused, among other things, on differences between types of search (e.g., exploratory and lookup), the influence of task complexity, prior knowledge, (cognitive) age, and search skills on search behaviour, query reformulation strategies and reformulation patterns, specificity of search queries, and the influence of query length on search success. Furthermore, some research regarding ‘searching information’ while using mobile phones has been conducted (e.g., Church & Oliver, 2011; Church & Smyth, 2008; Westlund et al., 2011). These studies examined in which situations people tend to use mobile search, and what interfaces encourage people to use longer queries on mobile phones. Results indicate that whereas in the past mobile search was mostly used on-the go, nowadays mobile search more and more replaces computer-based search at home, at school, or at work. However, there has not been much research regarding the influence of device type on the quality of the information problem solving process (Kammerer et al., 2018). Comparative research concerned searching the web with computers, smartphones, and iPhones for personal information needs (Kamvar, Kellar, Patel, & Xu, 2009), and did not concern information-based problems in educational settings. It seems the technological developments have gone faster than the pace of the scientific educational research (Kammerer et al., 2018).

The purpose of this study is to examine the influence of the type of device (computer or smartphone) and task type (fact-finding task and information-based problem) on the query formulation and reformulation part of the sub-skill ‘searching for information’ from the IPS-I model (Brand-Gruwel et al., 2009), when adolescents in secondary education are using a search engine to solve both a fact-finding and a more complex information-based problem. By examining this influence of type of device, the information searching part of the IPS-I model can be supplemented with knowledge of formulating and reformulating queries with smartphones. Furthermore, teachers can adapt their instructional approach by adding specific instructions about how to search the internet with smartphones, while solving information-based problems.

1.1 Theoretical framework

1.1.1 IPS-I

Information searching is a complex cognitive skill, which has been subject of scientific research for the past decades (for an overview see Dinet, Chevalier, & Tricot, 2012). Most of the research focused on skills and behaviours needed for information searching, but were not primarily based on situations where the internet was used to solve information problems. Specifically for information problem solving (IPS) while using the internet, Brand-Gruwel et al. (2009) developed the IPS-I model.

As can be seen in Fig. 1, the IPS-I model consists of five constituent skills, namely ‘Define information problem’, ‘Search information’, ‘Scan information’, ‘Process information’, and ‘Organize and present information’ and three conditional skills, namely ‘Reading skills’, ‘Evaluating skills’, and ‘Computer skills’. Furthermore, users will carry out regulation activities, such as monitoring, steering and evaluating, throughout the IPS-process (Brand-Gruwel et al., 2009).

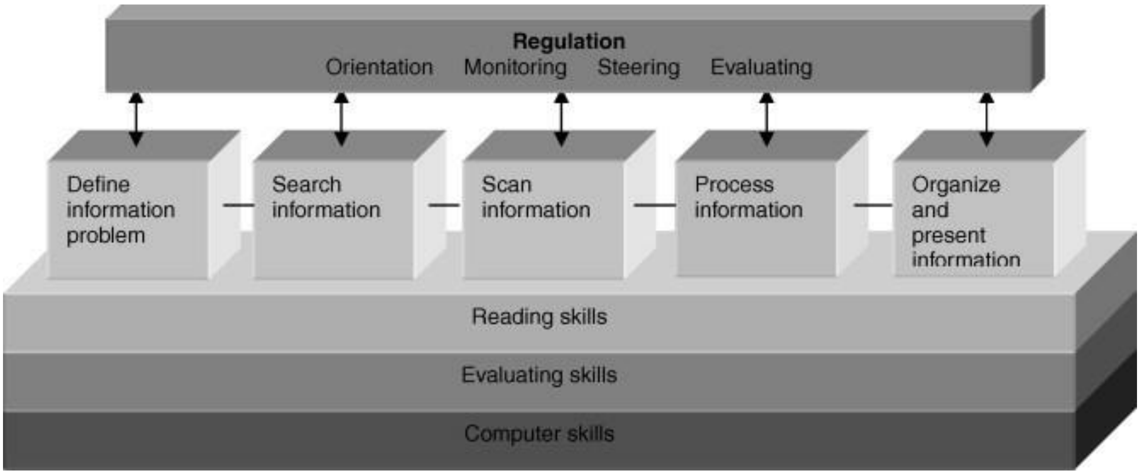

Fig. 1. The information problem solving using internet model (IPS-I model) (Brand-Gruwel et al., 2009)

1.1.2 Searching for information

The first step in solving an information-based problem is defining and understanding the problem (Brand-Gruwel et al., 2009; Sanchiz et al., 2017a). After the information problem is clear to the user, the information searching process, which is the focus of the present research, will start. There are different strategies possible to start the search: (a) content based searching by using a search engine, (b) entering an URL (web address) in the browser, (c) browsing by content, using links (Lazonder, 2000). In the present research the focus is mainly on the first strategy: ‘using a search engine’.

The process of this part of searching, by using a search engine, has been schematised by Sharit et al. (2008) into a model of information-seeking behaviour, as can be seen in Fig. 2. When using a search engine the first step is to formulate a search query that is relevant to the information problem (Brand-Gruwel et al., 2009; Monchaux et al., 2015; Sharit et al., 2008). The search engine will provide a ‘hitlist’ (list of results). Users will have to check and evaluate the results on quality, reliability and relevance to the information problem (Monchaux et al., 2015; Sharit et al., 2008; Wopereis, Brand-Gruwel, & Vermetten, 2008). If the user cannot solve the information problem using the results from the hitlist, the initial query will have to be reformulated. This process of formulating and reformulating is an iterative process as long as the information problem has not yet been solved (Brand-Gruwel et al., 2009; Jansen et al., 2007b; Karanam & van Oostendorp, 2016; Liu et al., 2010; Monchaux et al., 2015; Sanchiz et al., 2017a).

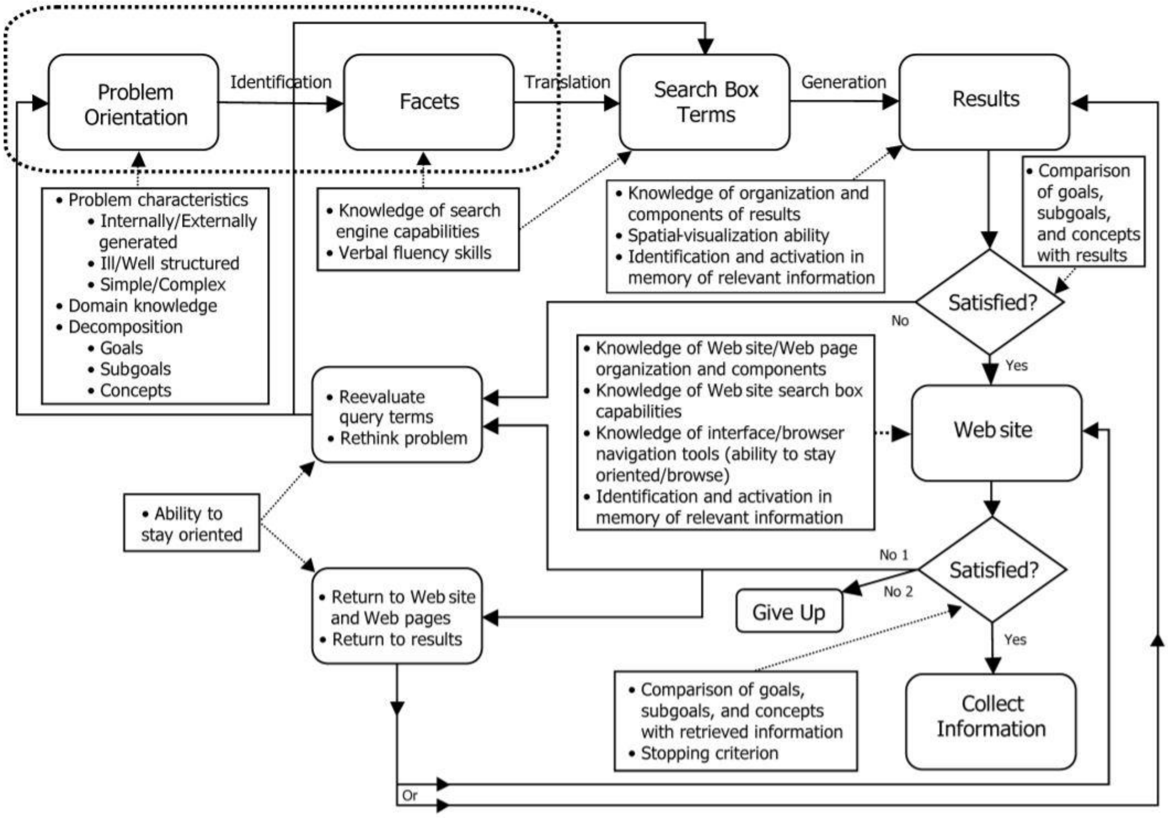

Fig. 2. A model of search engine information-seeking behaviour (Sharit et al., 2008).

1.1.3 Search query length

One of the factors influencing the success of the search (i.e., finding the required information), is search query length. Longer search queries are more likely to produce successful results than shorter search queries (Agapie et al., 2013; Belkin et al., 2003; Walhout et al., 2017). People, however, are more likely to produce short search queries (Agapie et al., 2013).

Previous research on search query length indicates that, on average, people use between two and three keywords in their searches while using a computer (e.g., Jansen & Spink, 2006). However, more recent studies indicate that children tend to use natural language queries, i.e., phrases or questions, instead of keywords (Bilal & Gwizdka, 2018; Kammerer & Bohnacker, 2012). The use of phrases and questions, lengthens queries to six words on average (Bilal & Gwizdka, 2018). Some previous research on mobile search indicates that query length while using mobile phones is similar to query length while using computers (e.g., Church & Smyth, 2008; Westlund et al., 2011). However, research by Kamvar et al. (2009) showed that search behaviour on computers and iPhones was rather similar, but that there were significant differences between computers and mobile phones, other than iPhones. Query length was significantly shorter for users of mobile phones (other than iPhones), compared to computer and iPhone users. It was hypothesised that the difference was due to the fact that it is easier to type on computers and iPhones than on other mobile phones.

Although most previous research indicates that search queries on both computers and mobile devices were relatively short, the search activities involved in these studies were mainly personal search activities used to retrieve simple facts. In information-based problems, for instance in an educational setting, task complexity has to be taken into account. Previous research indicates that people tend to use longer queries in complex tasks, than in simple fact-finding tasks (Chevalier, Dommes, & Marquié, 2015; Monchaux et al., 2015; Sanchiz et al., 2017b; Walhout et al., 2017). In simple tasks query length varies, on average, between two to three words, whereas in complex tasks query length varies, on average, from four to six words (Aula et al., 2010; Dommes et al., 2011).

Another factor influencing search query length is prior knowledge. People with more prior knowledge are able to produce more relevant keywords. Therefore, they are able to produce longer search queries than people with little prior knowledge (Sanchiz et al., 2017a; Sanchiz et al., 2017b).

1.1.4 Search query specificity

Besides search query length, search query specificity is another factor influencing the success of the search. According to Sanchiz et al. (2017b) semantic query specificity can be described as the extent to which queries are narrow, or broad. A narrow query consists mainly of keywords specific to the domain of the information problem, a broad query consists mainly of keywords that are general and not specific to the domain of the information problem.

Queries that are more specific are more likely to produce results that can be used to solve an information-based problem than queries that are broader (Brand-Gruwel et al., 2009; Sanchiz et al., 2017b). However, it should be noted that a specific query is no guarantee of a successful search. McCrudden and Schraw (2007) state that semantically specific queries contain keywords relevant to the domain, but not necessarily to the search goal. Specific queries, though, were more likely to produce results that contained the answer to the problem, or that contained information related to the search problem. This related information could in turn point searchers in the direction of new keywords they could use to adapt their query.

In order to formulate a specific query to solve an information-based problem, people will have to have performed the first step of the IPS-I model: definition of the problem (Brand-Gruwel et al., 2009). If the problem is clear to the searchers, they will know what the main question(s) and sub questions of the problem are, and they will have activated their prior knowledge. Based on the problem, questions and prior knowledge, domain specific keywords can be derived. Those keywords will be the input for their initial search query.

People with more prior knowledge will be able to formulate more specific queries than people with less prior knowledge. Previous research showed people with more prior knowledge produced less ambiguous keywords, and more domain specific keywords. Therefore their search queries tended to be more specific (Brand-Gruwel et al., 2009; Lei, Lin, & Sun, 2013; McCrudden & Schraw, 2007; Monchaux et al., 2015; Sanchiz et al., 2017a; Sanchiz et al., 2017b).

Task complexity also influences the semantic specificity of search queries. Previous research indicates that people tend to use more semantically specific queries for simple fact-finding tasks than for complex information-based problems (Liu et al., 2010; Sanchiz et al., 2017b). This can be explained by the fact that to solve a fact-finding task, a specific piece of information is required, while for complex information-based problems multiple pieces of information have to be combined (Liu et al., 2010).

1.1.5 Search query reformulations

According to the IPS-I model (Brand-Gruwel et al., 2009), it is important to orientate, monitor, steer, and evaluate during the entire IPS process. These are the regulation activities needed to successfully execute the IPS skill (see Fig. 1). When searching for information, it is likely that the results of the initial query do not provide a direct answer to the information-based problem. Students will use their regulation activities to determine whether the query has to be refined or replaced by a new query. The process of modifying queries and performing a new search is called query reformulation (Jiang & Ni, 2016).

According to Fidel (1985) there are three main reasons for people to reformulate their query. The first reason to reformulate is that there are too many search results. People will try to reduce the size of the set of results or try to get more relevant results on the first SERPs, because they expect this will help them discover more specific information of the concept they are searching. They try to achieve this by, for example, using more specific queries, or adding more words to the initial query (Hu et al., 2013). The second reason to reformulate, although unlikely nowadays, is that there are only a few search results. People will aim to broaden their search, to get a more expanded understanding of a concept (Fidel, 1985). They could achieve this by, for instance, using more general search queries (Hu et al., 2013). The third reason to reformulate is that the results are off target. People will aim to reformulate their query in order to get results suiting their information need (Fidel, 1985). This could be achieved by using queries involving different aspects of the search topic (Hu et al., 2013).

There are 13 different query modification types identified by Huang and Efthimiadis (2009). These modifications include, for example, reordering of words, word removal, word substitution and expanding of acronyms to the words that form the acronym. However, research in patterns of query reformulation indicates that specialisation and generalisation are the two basic modification patterns in query reformulation (e.g., Jansen et al., 2007a; Jansen et al., 2007b; Liu et al., 2010; Wildemuth et al., 2018). Previous research showed that about half of the initial queries were modified by searchers. Most of the time initial queries were reformulated to be more specific. If queries were reformulated again, they were likely to be generalized. Searchers tended to alternate between specialization and generalization while reformulating (Jansen et al., 2007a; Jansen et al., 2007b; Joo & Lee, 2011).

The process of reformulating is influenced by prior knowledge. It is difficult for people without much prior knowledge of a domain to produce domain specific keywords (Wildemuth, 2004).

Therefore, while reformulating novices tend to modify their queries only marginally. For example, they reformulate their query by substituting keywords with synonyms. In contrast, experts are able to use more different and complex reformulation strategies. For example, they are able to select relevant keywords, which they can use to formulate longer queries (Sutcliffe, Ennis, & Watkinson, 2000). Moreover, experts are better able to extract new keywords form the context of the SERP, or from the websites they visited (Dinet et al., 2012).

Prior knowledge also affects the preferences for types of reformulating behaviour. Previous research suggests that people with more prior knowledge tend to choose generalization more often as reformulation strategy. In contrast, people with less prior knowledge prefer specialization as reformulation strategy (Hu et al., 2013). These results can be explained by the initial queries of experts and novices. Liu et al. (2010) report that experts start by formulating more specific initial queries, whereas novices start by formulating more general initial queries. After the first search, experts will then broaden their queries if the results are not satisfying, whereas novices will narrow their search (Hu et al., 2013; Jansen et al., 2007a; Jansen et al., 2007b).

Another factor influencing reformulation behaviour is task type. Previous research indicates that both generalization and specialization were more often used in complex tasks than in fact-finding tasks (Hu et al., 2013; Karanam & van Oostendorp, 2016). Furthermore results of previous studies indicate that specialization was more often used in fact-finding tasks, whereas generalization was more often used in complex tasks (Karanam & van Oostendorp, 2016; Liu et al., 2010).

1.1.6 Number of search queries

As mentioned before, according to the IPS-I model it is important for people to regulate their activities, in order to solve an information-based problem correctly. If their search process is regulated well, people will need less iterations through the constituent skills in the model to reach their answer to the information-based problem. Specifically for the skill ‘searching for information’, this implicates that people will reach their answer with less queries needed (Brand-Gruwel et al., 2009). As can be seen in Fig. 2., if an initial query does not lead to a satisfying result, people will have to re-evaluate and rethink their actions, before entering a new query (Sharit et al., 2008). Thus, successful regulation will lead to less search queries needed to reach a satisfying answer to the information-based problem.

Regulation is not the only factor that affects the number of queries needed to successfully complete an information-based problem. Prior knowledge is another factor influencing the number of queries needed. People with more prior knowledge are better able to adapt their queries in order to find the information needed, than people with less prior knowledge. As a result, they need less queries before successfully solving an information-based problem (Hu et al., 2013). However, when faced with impossible problems (i.e., problems that could not be solved by searching the web, because no websites containing the answer existed), or in browsing sessions (i.e., sessions in which people search for information without a specific task or question), experts are able to produce more queries containing different domain specific terms than novices. This results in more queries used by people with more prior knowledge, compared to people with less prior knowledge (Monchaux et al., 2015; White, Dumais, & Teevan, 2009).

In addition to regulation activities and prior knowledge, task complexity is also a determining factor in the number of queries needed to solve an information-based problem. In a simple fact-finding task people need to find a specific piece of information, whereas for a complex information-based problem multiple pieces of information have to be combined. As a result there are less queries needed to solve a fact-finding task, than to solve a complex information-based problem (Chevalier et al., 2015; Karanam & van Oostendorp, 2016; Liu et al., 2010; Monchaux et al., 2015; Sanchiz et al., 2017a; Sanchiz et al., 2017b).

According to previous research device type can also influence the number of queries. Kamvar et al. (2009) showed that on average 1.94 queries were used on a desktop computer, and on average 1.70 queries were used on a mobile device. It was argued that computer users tend to reformulate more often, and mobile users, as text entry is more difficult than on a computer, tend to browse more, and use less reformulations.

1.2 Research questions and hypotheses

This thesis focuses on the information searching skill of the IPS-I model (Brand-Gruwel et al., 2009). The aim is to examine the influence of the type of device on the formulation and reformulation of search queries used in a search engine, while solving fact-finding and complex information-based problems.

In order to determine the influence of the type of device on search query formulation and search query reformulation the following two research questions are addressed:

(1) What is the difference in <u>search query length</u>, <u>search query specificity</u> and <u>number of queries used</u> between a group of adolescents in secondary school, who are using a smartphone, compared to a group of adolescents in secondary school, who are using a laptop, while solving a fact-finding and complex information-based problem?

(2) How do <u>search query length</u> and <u>search query specificity</u> change between a group of adolescents in secondary school, who are using a smartphone, compared to a group of adolescents in secondary school, who are using a laptop, while reformulating their search queries in order to solve a fact-finding and complex information-based problem?

Based on these questions the following hypotheses are formulated:

H1. Hypotheses on query length

Previous research indicates that search queries are longer for complex information-based problems than for simple fact-finding tasks (Chevalier et al., 2015; Monchaux et al., 2015; Sanchiz et al., 2017b; Walhout et al., 2017). It is expected that the present study will yield the same results (H1a).

Because it is easier to type on a computer keyboard than on a mobile screen (Kamvar et al., 2009), it is expected that search query length will be shorter on smartphones than on laptops (H1b).

As search queries are typically longer for complex tasks, the effect of device type, such that with smartphones queries are shorter than with laptops, should be more pronounced for complex tasks, whereas for simple tasks, queries might be rather short for both device types (H1c).

Furthermore, while reformulating queries people try to specialize or generalise their queries. They can do this, for example, by substituting words, adding terms, or subtracting terms (Huang & Efthimiadis, 2009). It is expected that due to differences in expected initial query length, there will also be a difference between query length while reformulating between smartphone users and laptop users (H1d) and between fact-finding tasks and information-based problems (H1e).

H2. Hypotheses on query specificity

Previous research indicates that queries are more semantically specific for simple fact-finding tasks than for complex information-based problems (Liu et al., 2010; Sanchiz et al., 2017b). In the present study it is also expected that queries will be more specific in fact-finding tasks than in complex information-based problems (H2a).

Because the search process on mobile devices is often more focused than the search process on computers (Kamvar et al., 2009), it is expected that smartphone users will formulate more semantically specific queries than users of laptops (H2b).

As search queries are typically more specific for fact-finding tasks, the effect of device type, such that with smartphones queries are more specific than with laptops, should be more pronounced for fact-finding tasks, whereas for information-based problems, queries might be rather general for both device types. (H2c).

People tend to alternate between generalization and specialization while reformulating (Jansen et al., 2007a; Jansen et al., 2007b). It is expected that this behaviour will be the same regardless of the task type (H2d) and device type (H2e), because of the alternating pattern.

H3. Hypotheses on number of queries

Just as in previous research (Chevalier et al., 2015; Karanam & van Oostendorp, 2016; Liu et al., 2010; Monchaux et al., 2015; Sanchiz et al., 2017a; Sanchiz et al., 2017b), it is expected that the number of queries will be higher to solve information-based problems than to solve simple fact-finding tasks (H3a). Furthermore it is expected that to solve an information-based problem more new queries, instead of adaptations of the initial query, will be used (H3b), because in an information-based problem multiple perspectives of a problem will have to be integrated (Brand-Gruwel et al., 2009; Mosenthal, 1998).

Since it is easier to type on a computer than on a mobile device (Kamvar et al., 2009), it is expected that computer users will use more queries than mobile users (H3c).

As more queries are used for information-based problems than for fact-finding tasks, the effect of device type, such that with laptops more queries will be used than with smartphones, should be more pronounced for information-based problems, whereas for fact-finding tasks, number of queries used might be rather the same for both device types (H3d).

2. Method

2.1 Design

The present study aims to determine the effect of device type on querying behaviour of adolescents in secondary school while solving fact-finding and complex information-based problems. To study this, an experiment using a mixed design was conducted, including both a between-subjects variable (device) and a within-subjects variable (task type). There were two between-subjects groups in the experiment, namely laptop and smartphone, and two within-subjects task conditions, namely fact-finding tasks and complex information-based problems. Participants were randomly assigned to either the smartphone condition, or the laptop condition and they were given both the fact-finding task and the complex information-based problem to solve. In order to assure that the two groups did not differ in their prior knowledge, self-reported prior knowledge on nuclear energy of all participants was measured before starting the search tasks.

2.2 Participants

A large secondary school in The Netherlands, with approximately 2200 students, agreed to provide participants for this experiment. Students of the target population were asked by means of an information letter, if they were willing to participate in the experiment. From the list of students who were willing to participate, 55 students were randomly selected.

Exclusion criteria: Students with hard lenses were excluded from participation, as hard lenses cannot be used in combination with an eye-tracker. Students who need glasses to read, were also excluded from participation, because the eye-tracker cannot be used in combination with glasses.

Inclusion criteria: This study focuses on comparative research in secondary education. Research shows that processing information is still difficult for juniors in secondary school (Walraven et al., 2008). That is why students in the senior years (third and fourth year; 11^{th} and 12^{th} grade) of the higher secondary education level and pre-university education level were chosen to participate in this experiment. Research indicates that these students are able to use strategic processes when processing information from several sources (Cho, 2014; Cho & Afflerbach, 2015).

Sample size: The present study is an exploratory study. Therefore, a power calculation cannot be done. To determine the sample size for the present study, sample sizes of recent studies into searching the web on small and large screens which are published in peer-reviewed journals have been examined. Kim, Thomas, Sankaranarayana, Gedeon, and Yoon (2015) studied the difference in search behaviour of students who performed an IPS-I task. The screen size acted as an independent variable in a between-group design. Using eye-tracking they collected data regarding fixation time, search speed, and the viewing path. The research was conducted with 35 participants, who performed the tasks on both a small screen and a large screen. The size of the sample for this study was set at a minimum of 50 participants.

From the third and fourth year of the higher secondary education level and pre-university education level (11th and 12th grade), 55 students volunteered to participate in the present experiment. To control for gender, age and educational level, participants were paired based on those attributes. Subsequently, one of the pair was randomly assigned to the smartphone group, and the other to the laptop group.

Data of seven participants had to be excluded due to technical problems. As a result, the group from which data was analysed contained 48 participants: as can be seen in Table 1, 23 participants in the laptop condition (M_{age} = 14.83, *SD* = .78, 15 males and 8 females, 18 in 11th grade and 5 in 12th grade, 10 in higher secondary education and 13 in pre-university education), and, as can be seen in Table 2, 25 in the smartphone condition (M_{age} = 14.88, *SD* = .88, 15 males and 10 females, 23 in 11th grade and 2 in 12th grade, 12 in higher secondary education and 13 in pre-university education). No significant differences were found in prior knowledge between students in the laptop (*M* = 5.65, *SD* = 1.80) and the smartphone condition (*M* = 5.16, *SD* = 1.49), $t(46) = 1.04$, $p = .306$.

Table 1

Participants in laptop condition

		Grade				
		11th grade (3rd year secondary education)		12th grade (4th year secondary education)		
		Educational level		Educational level		
		Higher secondary education	Pre-university education	Higher secondary education	Pre-university education	Total
Gender	Male	6	6	1	2	15
	Female	2	4	1	1	8
	Total	8	10	2	3	23

Table 2

Participants in smartphone condition

		Grade				
		11th grade (3rd year secondary education)		12th grade (4th year secondary education)		
		Educational level		Educational level		
		Higher secondary education	Pre-university education	Higher secondary education	Pre-university education	Total
Gender	Male	9	6	0	0	15
	Female	2	6	1	1	10
	Total	11	12	1	1	25

2.3 Materials

2.3.1 Task descriptions

The two tasks used in the present study can be classified according to the task description of Mosenthal (1998). The fact-finding task falls into the second category of Mosenthal (1998); tasks that require students to find concrete information. In this category students will have to find the specific information, while distractors are present. The fact-finding task in this study is: Please name five European countries that do not have nuclear power plants.

The complex information-based problem falls into the fifth and final category of Mosenthal (1998). In this category, abstract, ill-structured information must be localized and integrated. Here the student has to recognize themes in the text and compare information. This corresponds to the characterization of an IPS-I task in which information from multiple sources has to be localized, organized and synthesized (Brand-Gruwel et al., 2009). The complex information-based problem in this study is: Is stimulating nuclear energy a good idea to solve the climate problem? The students elaborate on their answer with argumentation in a short essay of half a page.

2.3.2 Instruments

Demographic data were collected using a short demographic questionnaire asking about the age, gender, grade and school level of the participant. To measure prior domain knowledge a single item that assessed self-reported prior knowledge was used. The students were asked to rate their prior knowledge on nuclear power plants on a scale from 1 to 10. The questionnaire was administered to each participant on paper during the experiment. No further personal data were collected via questionnaires.

2.3.3 Devices

Participants who were allocated to the computer group used a Lenovo Thinkpad T520 laptop with a 15.6 inch screen. They used Google Chrome as browser and Google as search engine. Participants who were allocated to the smartphone group used an Huawei Y6 smartphone with a 5.0 inch screen. They also used Google Chrome as browser and Google as search engine. The session of all participants was recorded with SMI Eye-tracking Glasses 60 Hz. These eye-tracking glasses work with iViewX software and record a video of the search session. For the purpose of this thesis only screen recordings were needed. However, since the present study was part of a larger study into search behaviour, the recording was made using the eye-tracking glasses.

2.3.4 Data storage

All data will be stored on the OU servers for a period of 10 years. The paper questionnaires cannot be traced to individual participants. The questionnaires have been transferred in SPSS and were then sent to the OU supervisors. Immediately after data collection, the informed consent letters have been sent to the OU.

2.4 Procedure

The school, teachers involved, and students of the secondary education school were informed about the research. By means of an informed consent form, the school management, students and parents of those students who have not yet reached the age of 16 have been asked for permission to conduct the study. The research took place at the school concerned in a separate room in which only the researcher and participant were present. The duration of a session was 50 minutes. The sessions were supervised by different researchers (master thesis students), one at a time per participant, who used the same prescribed instructions.

The session started with welcoming the participant. After this, the researcher gave an overview of the course of the session, namely: measurement of demographic variables, prior knowledge, adjustment of the eye-tracking equipment, fact-finding task and written response, complex information-based problem and essay response. This instruction is prescribed so that all researchers provided the same information. The researcher handed out the demographic questionnaire and asked the participant to fill it out and hand it in when finished. The participants then received a questionnaire to measure prior knowledge. After finishing the questionnaire, the eye-tracking equipment was calibrated, and its operation was explained to the participant.

After the calibration of the eye-tracking equipment, the participant received an answer sheet with the fact-finding task on it. The researcher explained the task to the participant by saying: "Please search on the internet for five European countries that do not have nuclear power plants and write the answer down on your answer sheet. You will have five minutes to finish this task." The researcher asked the participant to repeat the assignment in their own words. After handing in the fact-finding task, the participant received the answer sheet containing the complex information-based problem, and a piece of paper to make notes. The researcher explained the task to the participant by saying: "In a moment you will perform a task in which you will have to solve an information-based problem. The question is: Is stimulating nuclear energy a good idea to solve the climate problem?" The researcher asked the participant to repeat the assignment in their own words. After that the researcher said: "You will have 15 minutes to search the internet for information about this question. You are allowed to take notes. At the end of the search task, you will have to write an essay with your answer and arguments supporting your answer on half a page. You will get a maximum of 10 minutes to finish your essay. After receiving the essay, the researcher thanked the participant for their cooperation.

2.5 Dependent measures

To determine the effect of device type and task type on querying behaviour, six dependent variables are operationalized:

- Dependent variable 1: Search query length. To determine search query length, the number of words that make up a query are counted. This was done by counting the number of words typed in for each search trial that is recorded in the eye-tracking recording.

- Dependent variable 2: Difference between initial query length and average query length after initial query. The average query length of the search queries after the initial query was calculated. This average length was subtracted from the initial query length.

- Dependent variable 3: Specificity of search terms. The method of Sanchiz et al. (2017b) was used to determine the specificity of search queries. Search query specificity refers to whether search queries are formulated globally, without using domain-specific terms, or formulated specifically, using domain-specific search terms. To establish a score for specificity, all entered keywords per query in the information-based problem, as obtained from the eye-tracking recording, were scored independently by two researchers. Each global keyword has been assigned a score of 1, each domain-specific keyword has been assigned a score of 3 and each keyword that is between global and domain-specific has been assigned a score of 2. The quotient was then calculated from the sum of the scores and the number of keywords used. This is to prevent that the length of the search query will influence the specificity score. The specificity score was established for each individual search query. Pearson’s correlation between the 2 researchers was high, $r = .78$, $p < .001$. The process of calculating specificity was therefore repeated by one researcher for the fact-finding task.

- Dependent variable 4: Difference between initial query specificity and average query specificity after initial query. The average query specificity of the search queries after the initial query was calculated. This average specificity was subtracted from the initial query specificity.

- Dependent variable 5: Number of searches before an answer is formulated. In order to determine the number of searches before an answer is formulated, the total number of searches performed was counted, regardless of whether they provide relevant information or not. This was done by counting every search that was recorded in the eye-tracking recording.

- Dependent variable 6: Percentage of new search queries, while reformulating, relative to the total number of reformulations. First the reformulated queries were coded as an adaptation of the initial query, or as a new query. After that the percentage of new queries was calculated.

2.6 Data analysis

Before analysing the data, outliers were corrected to winsorized estimators (Field, 2014). To analyse the data, 2 x 2 mixed ANOVAs were used for all dependent variables with device type as between-subjects factor, and task type as within-subjects factor. The significance level was set at .05. Unless stated otherwise, results of one-tailed tests are reported. Homogeneity assumption was respected (Levine’s test $p > .05$).

3. Results

2 x 2 mixed ANOVAs were performed with experimental condition as between-subject factor and task type as within-subjects factor. Analyses were made on search query length, search query specificity, number of queries used, difference between initial query length and average query length after initial query, difference between initial query specificity and average query specificity after initial query, and percentage of new queries while reformulating, relative to the total number of reformulations. Because there was no significant difference in prior knowledge between the different conditions, prior knowledge was not used as covariate in the analyses.

3.1 Search query length

Other than expected in Hypothesis H1a, results of the mixed ANOVA showed that there was no significant main effect of task type on average search query length, $F(1, 46) = 2.15$, $p = .075$, $r = .21$. This indicates that the average search query length in the different task types was similar. Also other than expected in Hypothesis H1b, no significant main effect of device type on average search query length has been found, $F(1, 46) = .001$, $p = .487$, $r = .01$. These results indicate that the average search query length was similar for users of laptops and smartphones. Also in contrast with expectations in Hypothesis H1c, no significant interaction effect between device type and task type on average search query length has been found, $F(1, 46) = .03$, $p = .429$, $r = .03$.

If we only take the initial search queries into account (i.e., the start of the search process), a significant main effect of task type on search query length has been found, as expected in Hypothesis H1a, $F(1, 46) = 5.04$, $p = .015$, $r = .31$. As can be seen in Table 3, participants produced shorter initial queries for the fact-finding task ($M = 3.90$, $SD = 1.70$) than for the information-based problem ($M = 5.29$, $SD = 4.49$). However, also in the initial query length no significant main effect of device type has been found, $F(1, 46) = .12$, $p = .368$, $r = .05$. Furthermore, there was no significant interaction effect between device type and task type on initial search query length, $F(1, 46) = .80$, $p = .188$, $r = .13$.

Table 3

Descriptive statistics of initial search query length in different task types

	Experimental Condition	Mean	Std. Deviation	N
Length of search query 1 fact-finding task	Laptop	4.04	1.77	23
	Smartphone	3.76	1.67	25
	Total	3.90	1.70	48
Length of search query 1 information-based problem	Laptop	4.87	4.30	23
	Smartphone	5.68	4.71	25
	Total	5.29	4.49	48

3.2 Search query length after initial query

Other than expected in Hypothesis H1d, results of the mixed ANOVA showed that there was no significant main effect of device type on search query length while reformulating, $F(1, 29) = .18$, $p = .674$ (two-tailed), $r = .08$. These results indicate that the differences in search query lengths between the initial query and the average of the queries after the initial query were similar for users of laptops and smartphones. Also other than predicted in Hypothesis H1e, there was no significant main effect of task type on search query length while reformulating, $F(1, 29) = 1.69$, $p = .203$ (two-tailed), $r = .23$. This indicates that the differences in search query lengths between the initial query and the average of the queries after the initial query in the different task types were similar. Furthermore, no significant interaction effect between device type and task type on search query length, while reformulating, has been found, $F(1, 29) = .43$, $p = .515$ (two-tailed), $r = .12$.

3.3 Search query specificity

As expected in Hypothesis H2a results of the mixed ANOVA showed a significant main effect of task type on average search query specificity, $F(1, 46) = 19.54$, $p < .001$, $r = .55$. As can be seen in Table 4, participants produced, on average, semantically more specific terms for the fact-finding task ($M = 2.03$, $SD = .24$) than for the information-based problem ($M = 1.78$, $SD = .38$). However, other than predicted in Hypothesis H2b no significant main effect of device type on average query specificity has been found, $F(1, 46) = .08$, $p = .393$, $r = .04$. This indicates that the average semantic specificity of search queries was the same for laptop users and smartphone users. Also other than expected in Hypothesis H2c there was no significant interaction effect between device type and task type on average search query specificity, $F(1, 46) = 2.13$, $p = .076$, $r = .21$.

Table 4

Descriptive statistics of average search query specificity in different task types

	Experimental Condition	Mean	Std. Deviation	N
Average search query specificity fact-finding task	Laptop	2.07	.26	23
	Smartphone	2.00	.23	25
	Total	2.03	.24	48
Average search query specificity information-based problem	Laptop	1.73	.32	23
	Smartphone	1.83	.43	25
	Total	1.78	.38	48

3.4 Search query specificity after initial query

As expected in Hypothesis H2d results of the mixed ANOVA showed that there was no significant main effect of task type on search query specificity while reformulating, $F(1, 29) = 2.03$, $p = .165$ (two-tailed), $r = .26$. This indicates that the differences in search query specificity between the initial query and the average of the queries after the initial query in the different task types were similar. Also in line with expectations of Hypothesis H2e, no significant main effect of device type on search query specificity while reformulating has been found, $F(1, 29) = .14$, $p = .713$ (two-tailed), $r = .07$. These results indicate that the differences in search query specificity between the initial query and the average of the queries after the initial query were similar for users of laptops and smartphones. Furthermore, no significant interaction effect between device type and task type on search query specificity while reformulating, has been found, $F(1, 29) = 4.12$, $p = .052$ (two-tailed), $r = .35$.

3.5 Number of search queries

Other than expected in Hypothesis H3a, results of the mixed ANOVA showed that there was no significant main effect of task type on number of search queries, $F(1, 46) = .24$, $p = .315$, $r = .07$. This indicates that number of queries needed to solve the different task types were similar. Also other than predicted in Hypothesis H3c, no significant main effect of device type on number of queries has been found, $F(1, 46) = 2.57$, $p = .058$, $r = .23$. These results indicate that number of queries needed to finish the tasks were similar for users of laptops and smartphones. As expected in Hypothesis H3d, a significant interaction effect between device type and task type on number of queries needed has been found, $F(1, 46) = 5.54$, $p = .012$, $r = .33$. The interaction graph (Fig. 3) shows that whereas the number of search queries is almost equal in fact-finding tasks on both laptops ($M = 2.96$, $SD = 1.61$) and smartphones ($M = 3.08$, $SD = 1.50$), the number of queries needed to solve information-based problems increases for laptop users ($M = 3.87$, $SD = 2.32$) and decreases for smartphone users ($M = 2.48$, $SD = 1.53$).

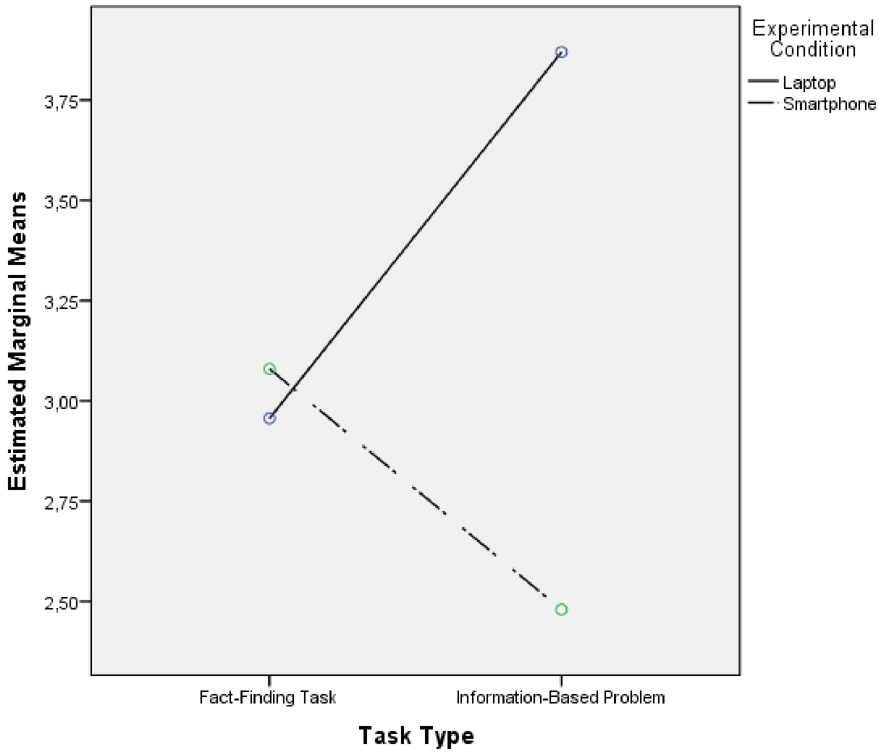

Fig. 3. Marginal means of number of queries in different task types and different device types

3.6 Reformulation strategies

When reformulating queries, students either chose to adapt their query (i.e., specialization, generalization, correction), or formulate a new query. As expected in Hypothesis H3b, results of the mixed ANOVA showed that there is a significant main effect of task type on the percentage of new queries used relative to the total number of reformulations, $F(1, 29) = 10.29$, $p = .002$, $r = .51$. As can be seen in table 5 participants produced significantly more new queries in order to solve the information-based problem ($M = 32.56$, $SD = 41.25$), than in order to solve the fact-finding task ($M = 6.58$, $SD = 12.71$). No significant main effect of device type on percentage of new queries has been found, $F(1, 29) = .12$, $p = .731$ (two-tailed), $r = .06$. Furthermore, no significant interaction effect between task type and device type on percentage of new queries has been found, $F(1, 29) = .21$, $p = .652$ (two-tailed), $r = .08$.

Table 5

Descriptive statistics of percentage of new queries, relative to total number of reformulations in different task types

	Experimental Condition	Mean	Std. Deviation	N
Percentage of new queries while reformulating in fact-finding task	Laptop	6.23	12.47	18
	Smartphone	7.05	13.54	13
	Total	6.58	12.71	31
Percentage of new queries while reformulating in information-based problem	Laptop	35.23	40.90	18
	Smartphone	28.85	43.12	13
	Total	32.56	41.25	31

4. Discussion

This study aimed to determine the influence of device type and task type on the query formulation and reformulation part of the subskill 'searching for information' from the IPS-I model (Brand-Gruwel et al., 2009). For that purpose, participants had to solve both a fact-finding task and an information-based problem on either a laptop or a smartphone. Results obtained from this study will be discussed below.

4.1 Effects of device type and task type on search query length

Results of the present study partly corroborated prior known effects of task type on search query length (Chevalier et al., 2015; Monchaux et al., 2015; Sanchiz et al., 2017b; Walhout et al., 2017). As hypothesized (H1a), students formulated longer initial search queries for the complex information-based problem than for the fact-finding tasks. However, taking all formulated queries into account, no significant differences in search query length were found for the different task types. Results can be explained by the reformulation strategy used. In fact-finding tasks students mostly adapted shorter queries by adding keywords to their initial query, whereas in information-based problems students adapted longer queries by subtracting keywords, or formulated new and shorter queries.

Other than hypothesized (H1b) and in contrast with previous work by Kamvar et al. (2009), no significant differences were found in search query length for smartphone users, or laptop users. It was argued by Kamvar et al. (2009) that typing on mobile phones is more difficult than typing on laptops, resulting in shorter queries on mobile phones. However, in the present research students did not have difficulties typing queries on mobile phones, resulting in equal search query length. Students use their smartphones in every-day life, and are used to typing on their screens. Westlund et al. (2011) call these users connected users. They use their mobile phone not only for basic communication, but to be connected to the internet on an everyday basis. It could be argued that students in secondary education nowadays use their phones more than they use computers and laptops, so typing on their screens is even more common for them than typing on a keyboard of a laptop.

Another explanation for the equality in query length for both device types is the use of auto-complete and query suggestions. Students used google as a search engine. On both laptops and smartphones google provided query suggestions, or auto-complete options. Students were tempted to use these auto-completed search terms, thereby muting the effect of typing on different keyboards. This is in line with previous research by Niu and Kelly (2014). Their study showed that people tend to use query suggestions, especially when they have little knowledge of a subject, or as the problem is difficult.

It was expected that as queries were longer in complex tasks than in fact-finding tasks, device type would have a reinforcing effect, so that in the laptop condition queries in the complex task would be longer than in the smartphone condition, whereas in the fact-finding task lengths in both conditions would be rather similar (H1c). However, no significant interaction effect has been found. This can be explained by the equality in query length in both experimental conditions. Because in both the laptop and the smartphone condition, query length was equal, device type was not reinforcing query length in the complex task.

Because of differences in initial query length, it was expected that the query length while reformulating, would also be different for laptop and smartphone users (H1d), and for the fact-finding task and information-based problem (H1e). However, no significant main effects were found, thus rejecting both hypotheses. Students reformulated their queries in the same way, regardless of the device they were using. As query length was equal in both the laptop and smartphone condition, adding and subtracting keywords or replacing their query by another query in the same way, resulted in the same query length while reformulating in the different experimental conditions. However, although there was a significant difference in initial query length in the different task types, no significant difference was found in query length while reformulating. The relative changes made by students in the queries while reformulating were more or less equal, resulting in no differences in query length.

Although query length did not differ when students reformulated their queries, between different device types and for the different task types, the reformulation behaviour differed between the two task types. Whereas in order to solve the fact-finding task students made more alterations to their initial query, they produced relatively more new queries in order to solve the information-based problem. Indeed, in the fact-finding task students formulated an initial query, with which they expected to solve the task. If they were not successful, they mostly tried to adapt this initial query in order to finally find the answer. In contrast, in order to solve the information-based problem students formulated an initial query, to find some aspects of the problem. After they had successfully found some part of the solution to the problem, they tended to formulate a new query to find another part of their answer. This is as expected (H3b) and in line with previous research of Liu et al. (2010), who showed that when users found a piece of useful information (i.e., part of the solution to their information based problem), they tended to use a new query rather than adapting their previous query.

4.2 Effects of device type and task type on semantic search query specificity

Results obtained on semantic specificity of search queries in this study, showed that as hypothesized (H2a) and in line with previous works (Liu et al., 2010; Sanchiz et al., 2017b), queries were more specific in fact-finding tasks than in information-based problems. Liu et al. (2010) argued that in fact-finding tasks, people had to search for specific information, resulting in more specific queries, than in open ended problems, where multiple sources of information were needed, resulting in more broader search terms. The same search behaviour was observed in the present study, suggesting that in order to solve information-based problems, more general search terms are needed to cover all aspects of the problem.

In addition to the nature of the information needed, in both problems, the complexity of the problem could also influence semantic specificity of queries. As was argued by Sanchiz et al. (2017b), complex problems require more comprehension processes. In order to save some cognitive resources for browsing and navigation, participants (in their study mainly older participants) produced less specific queries. Because they did not use cognitive resources to produce highly domain specific keywords, they could use these resources to process the information on the SERP and on the different websites.

It could be argued that participants in the present study also needed cognitive resources to process information on the SERP and websites, resulting in less cognitive space to formulate domain specific keywords. Participants were young adolescents, who should be capable of using regulation strategies, while processing multiple sources of information (Cho & Afflerbach, 2015). However, participants in this study seemed to have to use a considerable amount of effort to regulate their search process in solving the information-based problem. Although this might not influence formulating their initial query, it could be argued that while reformulating queries in information-based problems, they had less cognitive space available to come up with specific terms, than when solving a more simple fact-finding task.

Other than expected (H2b), and contrary to previous research (Kamvar et al., 2009), semantic specificity did not differ between smartphone, and laptop users. It was expected that mobile search was more focused, due to the nature of the device, resulting in more specific search terms. However, while this might be the case in open-ended private search sessions, in this study participants used a goal-based approach, based on the problem at hand, regardless of the device they were using. It could be argued that students in an educational setting only base their search queries and strategy on the problem, because they are used to solve these problems in a specific way. In addition to that, the interface of mobile browsers and desktop browsers is mostly the same nowadays, which resulted in device type being of no influence in formulating their queries.

Other than expected (H2c) no significant interaction effect has been found between task type and device type on semantic specificity. This is due to the fact that the specificity of search queries was equal in both the laptop and smartphone condition.

In line with previous studies (Jansen et al., 2007a; Jansen et al., 2007b) and as predicted (H2d, H2e), query reformulation behaviour consisted, among other things, of an alternating pattern of specialization and generalization. This resulted in the same semantic specificity of query reformulations regardless of the device type or the task type. These results confirm that students use regulation strategies (Brand-Gruwel et al., 2009) while solving information problems in an educational setting. If their initial query did not yield the requested information, students decided to either broaden their search by generalization, if their query was too specific, or narrow it down by adding specific terms, or subtracting general terms, if their query was too broad. Other than specialization and generalization, participants in this study also produced new queries or adaptions of their query with the same specificity, for example by word substitution (e.g., ‘nuclear powerplant England’, and ‘nuclear powerplant France’). However, these strategies did not result in differences in semantic specificity, because students generally behaved in the same way while reformulating.

4.3 Effects of device type and task type on number of search queries

As expected (H3d) and in line with previous research (Kamvar et al., 2009), there was a significant interaction of device type and task type on number of queries used. Indeed students used significantly more queries in solving information-based problems on laptops than on smartphones, whereas the number of queries for both device types was rather equal in solving fact-finding tasks. Kamvar et al. (2009) suggested in their study that this was due to the fact that it is more difficult to type on a screen than on a keyboard of a computer. However, as stated before, in this study students seemed to have no problem in using their keyboard on the mobile screen. Results could be explained, though, by the differences in usability of the browsers. In mobile search, students mostly carry out one search at a time, after which they open and review a website, before returning to the SERP again. In search activities on laptops students are able to use multiple tabs at a time, in which they perform searches simultaneously. Although the use of tabs is also possible on smartphones, it is less user-friendly than on a laptop, resulting in less usage of simultaneous search.

In contrast with prior known empirical results about the influence of task type on number of queries needed to solve the problem (Chevalier et al., 2015; Karanam & van Oostendorp, 2016; Liu et al., 2010; Monchaux et al., 2015; Sanchiz et al., 2017a; Sanchiz et al., 2017b), and other than expected (H3a), in this study no significant effect of task type on number of queries has been found. A number of students struggled with the fact-finding task and were not able to find the correct answer by using only a few queries. In contrast, a number of students were able to find websites with most of the information needed to solve the information-based problem, only by using a few queries. By using only a few queries and in some instances only one, students approached the information-based problem as if it were a fact-finding task. Because such a website was available, where students could find pro-arguments, as well as con-arguments to the question stated in the information-based problem, this compromised the results on number of queries needed.

5. Conclusion: implications and limitations

This study was designed to examine the influence of device type and task type on querying behaviour. Results showed that device type only influenced the number of queries used in information-based problems. These results implicate that in secondary education, students could use both laptops and smartphones while searching for information. Only when solving information-based problems, it is advisable to use laptops instead of smartphones, as it is easier to use multiple tabs and perform searches simultaneously on laptops than on smartphones.

With regard to task type, it was found that queries were longer in information-based problems, than in fact-finding tasks, whereas queries were more specific in fact-finding tasks than in information-based problems. These results corroborate prior findings (Chevalier et al., 2015; Liu et al., 2010; Monchaux et al., 2015; Sanchiz et al., 2017b; Walhout et al., 2017), thus reinforcing the plausibility of these results.

Furthermore, results of this study add to the knowledge base supporting the IPS-I model. This study adds the usage of different devices to the ‘searching for information’ subskill of the IPS-I model (Brand-Gruwel et al., 2009). It could be concluded that searching for information proceeds mainly in the same way on smartphones, and laptops.

Although this study provides new evidence-based insight in searching with different device types, several limitations need to be overcome for future works. The sample size in this study was quite small, which may have challenged the statistical analyses. Moreover, only two short tasks were used in this study. Therefore the influence of task type should be interpreted cautiously. In future studies multiple tasks of varying complexity and length could be used to confirm the influence of task type on querying behaviour, while searching with different devices.

Furthermore, students of only one school in a metropolitan area participated in this study. To extrapolate results to all students in secondary education, future research should be conducted in different schools in both metropolitan areas and in the countryside. It could be the case that familiarity with searching the internet and using smartphones varies in different regions. In addition, students of only the highest educational levels participated in this study. These students tend to have more experience in solving complex problems than students in the lower educational levels. Furthermore students of only the 11^{th} and 12^{th} grade participated. These students already have some experience in solving information problems, whereas students in lower grades might not have much experience, and students in the higher grades might have more experience, resulting in different search behaviour. In order to determine the influence of device type and task type on querying behaviour of students in secondary education, future research should focus on students of different educational levels, and in different grades.

Nowadays, auto completion and query suggestions are customary elements of search engines. Because the Google search engine also provided these options, students were, just as participants in previous research (Niu & Kelly, 2014), tempted to use these suggestions, especially if the complexity increased. This behaviour could have compromised the results, because the queries they used, based on suggestions, or auto complete option, would not have been the queries by their own choice. In that case, these functions of the search engine could have muted the effect of device type and task type on querying behaviour. Although it could be valuable to focus on querying behaviour without these functions, the use of these functions is conventional nowadays, limiting the external validity of such a study. However, a study with multiple tasks of different length and complexity, as suggested before, could provide more insight in querying behaviour, taking into account the quality of the query suggestion.

In order to solve the complex information-based problem in this study, students had to combine information from multiple sources in order to find arguments in favour or against the statement in the problem. However, by entering the question into the search engine, one of the results on the first SERP was a website containing several pro-arguments, and con-arguments. In case students noticed that website, and used it to solve the information-based problem, they approached this problem as if it were a fact-finding task. In future works it is important to check whether there exists a website containing most, or all of the information needed to solve the problem. In that case, another information-based problem will have to be designed.

Based on the findings of this study it could be recommended that teachers integrate smartphone usage in the classroom. As mentioned before, nowadays almost all students have access to a smartphone with internet connection. However, not all students have access to their own personal computer, tablet, or laptop (CBS, 2018). When students are faced with problems they could not solve without the internet, teachers could encourage the usage of smartphones. By means of that, teachers could enrich their lessons with problems that could not be solved by consulting the textbook and that require information-problem-solving skills.

Although embedding smartphone usage in the educational setting could have benefits, there are also downsides teachers will have to take into account. Firstly, if students are asked to elaborate on an information-based problem by writing an essay with a considerable length, they might prefer a laptop or desktop computer over a smartphone. In that way they are able to work on their essay in a word processor, simultaneously with their search process.

Secondly, a smartphone could be a distractor. Various entertainment and instant-messaging apps are within reach at the smartphone and could cause students to pay more attention to those distractors than to the teacher. To overcome this, teachers should establish clear rules regarding smartphone usage and students will have to comply with these rules. (Anshari et al., 2017). However, if they succeed, smartphone usage could offer possibilities in creating dynamic learning environments where students could access and integrate multiple sources of information in constructing their own knowledge.

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Appendices

Appendix A: Demographic questionnaire

Formulier 1

In te vullen door onderzoeker:	
Proefpersoon	
Datum	

- **Omcirkel of vul in wat op jou van toepassing is:**

Leeftijd						
13	14	15	16	17	18	19

Geslacht
………………………………………………………………………………………………………

Leerjaar			
3	4	5	6

Schoolniveau	
havo	vwo

Van welk merk is je huidige smartphone?			
Apple	Samsung	Huawei	Anders, namelijk:
			……………………..

Welk apparaat gebruik je het meest om informatie op het internet te zoeken?			
Smartphone	Tablet	Laptop	Desktop PC

Hoe vaak zoek je informatie op het internet?			
Dagelijks	Meermaals per week	Een keer per week	Minder dan een keer per week

Appendix B: Self-reported prior knowledge

Formulier 2

- **Hieronder staan 4 vragen.**
- **Geef antwoord op de vragen door een cijfer te omcirkelen.**

1.Hoeveel weet je over kerncentrales?									
Geen kennis over kerncentrales									Expert over kerncentrales
1	2	3	4	5	6	7	8	9	10

2.Hoeveel weet je over klimaatverandering?									
Geen kennis over klimaat-verandering									Expert over klimaat-verandering
1	2	3	4	5	6	7	8	9	10

Appendix C: Fact-finding task

Opdracht 1

Zoek op het internet vijf EU-lidstaten op die geen kernreactoren hebben en schrijf deze op het antwoordblad.

Antwoord:

Appendix D: Information-based problem

Opdracht 2

Werk hieronder jouw antwoord met argumenten uit op de vraag:

Is het stimuleren van kernenergie een goed idee om klimaatverandering aan te pakken?

Aantekeningenblad