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Information-seeking behaviour and academic success in higher education: Which search strategies matter for grade differences among university students and how does this relevance differ by field of study?

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Abstract Today, most college students use the Internet when preparing for exams or homework. Yet, research has shown that undergraduates' information literacy skills are often insufficient. In this paper, we empirically test the relation between information-seeking strategies and grades in university. We synthesise arguments from the literature on information-seeking behaviour and approaches to learning in tertiary education. Building on the distinction between deep- and surface-level learning, we develop a classification of online search strategies and contrast it with traditional information behaviour. Multivariate analyses using a two-wave online survey among undergraduate students at a German university indicate that using advanced online information-seeking strategies is a significant and robust predictor of better grades. However, there are notable differences between subject groups: Traditional information behaviour is still crucial in the humanities. Advanced search strategies are beneficial in all settings, but only one in four students uses these early on, while this share increases to around 50% over the course of studies.

Keywords Information-seeking behaviour · Approaches to learning · Information literacy skills · Learning environments · Achievement · Higher education

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Introduction

Since the exponential diffusion of connections to the World Wide Web both on stationary and mobile devices, online media have tremendously gained importance as means of acquiring information. The literature debates whether computer skills and related technical skills enhance individual earnings (Borghans and Ter Weel 2007), or foster the quality of work life (Autor et al. 2003) or school performance (Attewell 2001). There have also been long-standing debates about the impact of digital media competencies (Cox and Marshall 2007) or social media use (Margaryan et al. 2011) on learning outcomes in higher education.

In this paper, we focus on the effects of information-seeking behaviour on grades among undergraduate students who have been raised as digital natives but still may not necessarily possess the information skills demanded in higher education. Recently, several studies have revealed a lack of information literacy, i.e. skills related to finding and critically evaluating information found online, among undergraduate students (Callinan 2005). Yet, less is known about how academic achievement in higher education is influenced by students' information-seeking behaviour in general and by their usage of traditional routines or specific online media in particular. This is an important gap in the literature for two reasons. First, from a microperspective, educational psychologists have identified students' *deep*-level and *surface*-level approaches to learning as important determinants of achievement in secondary and higher education (Busato et al. 2000; Chin and Brown 2000; Richardson et al. 2012). An elaborate online information-seeking behaviour could be an important indicator of a deep-level approach to learning that has so far been neglected in empirical studies predicting academic achievement. Second, from a meso-level perspective, students' learning environments, influenced by their respective academic field, have been observed to affect both deep-level and surface-level approaches to learning as well as information-seeking behaviour (Baeten et al. 2010; Lizzio et al. 2002). Therefore, the extent to which more elaborated online information-seeking behaviour actually pays off in terms of students' grades could depend on subject-specific informational environments.

Elaborating on these research gaps, we aim to answer the following two research questions. Do higher education students who use more elaborate online information-seeking strategies get better grades compared with their less elaborately seeking counterparts? And if so, is this effect moderated by subject-specific learning environments? To answer our research questions, we use specific panel data from a cohort of German undergraduate students, and we compare our results to students who use traditional information-seeking strategies.

In the following section, we first present a conceptual framework, drawing on existing models of student achievement in higher education. From a microperspective, we identify deep-level and surface-level information-seeking behaviour as indicators of student approaches to learning in higher education. From a mesoperspective, we highlight the importance of how the organisational culture of the respective study subject influences students' learning environments. Having summarised our theoretical model, we proceed to describe our data, indicators and methods of analysis in the next section. We then move on to discuss both descriptive and multivariate results. We conclude with an interpretation of our main findings and an outlook towards further research.

Theoretical background, state of research, and hypotheses

Academic success in higher education is often related to psychological factors such as students' self-efficacy, self-regulated learning and other meta-cognitive skills (see review by Richardson et al. 2012) as well as to socio-economic and institutional factors such as organisational structures influencing the learning environment or family background (Tinto 1975). Moreover, deep- and surface-level approaches to learning are robust predictive concepts of academic success in higher education (Zeegers 2004).

As a useful analytical distinction, theoretical models on achievement in higher education can be grouped into micro-, meso- or macro-level perspectives. Many sociological, psychological and economic theories adopt a microperspective, while organisational theories follow a macro- or mesoperspective. Building on this distinction, we extend preceding research in two respects. From a microperspective, we link students' information-seeking behaviour to achievement in higher education. From a mesoperspective, we look at learning environments, understood as a mediating layer between the learner and the organisational culture (following, e.g. Brennan et al. 2010). This conception of learning environments focuses on the interaction between the students with their individual skills and behaviour and the rules and regularities of the respective discipline or department determining, e.g. how learning is affected by "curriculum codes" that frame how knowledge is organised and how much control students have over content and pedagogy of the teaching (Bernstein 2000).

Information-seeking behaviour and approaches to learning

Individual information-seeking behaviour in higher education is a relatively novel field of research. There have been several exploratory studies that have described and classified students' information-seeking in university (see Timmers and Glas 2010). Among others, Olsen and Diekema (2012) have used qualitative methods to categorise information-seeking strategies of students in higher education. Bilal and Kirby (2002) and Thatcher (2008) have used descriptive and inductive quantitative approaches for the same objective. A common finding of this either qualitative or descriptive quantitative literature is that students often use general-purpose search engines such as *Google* but rarely select "advanced search" options. Moreover, many students are not aware of databases or search engines specifically designed to find academic content such as library catalogues, *Web of Science*, *JSTOR* or *Google Scholar* (Callinan 2005). Olsen and Diekema (2012) aptly label this behaviour the information "comfort zone" where students "would exhaust their searches in their known options for information rather than look for new places to find information" (p. 4).

Just as searchers' expertise in a particular domain is associated with better search inquiries (Dinet et al. 2012), students' knowledge and usage of scholarly journals typically increase over time. Yet, information-seeking behaviour of more advanced students may still remain below the demands of teaching staff. While both graduate and even postgraduate students regard themselves as intermediate or expert users, lower-level Web search tactics are still the dominant form of information-seeking behaviour in both groups (Civilcharran et al. 2015).

In contrast to that, students with higher online self-efficacy show more elaborate forms of information-seeking behaviour and even learn better (Tsai and Tsai 2003). This finding can be related to experimental evidence by Weber et al. (2018): undergraduate students who were trained in information literacy skills used more scholarly databases than a control group. Still, the level of sophistication of search queries remained limited even immediately after the

training. Similarly, evidence from survey data suggests that increasing students' Web expertise does not necessarily increase their meta-cognitive strategies (e.g. purposeful thinking, selecting main ideas, evaluation strategies) as well (Thatcher 2008; Tsai 2009).

This raises the question to what extent information-seeking strategies are related to student achievement. In general, most of the literature on the effects of online media and information-seeking behaviour has been limited to compulsory education (Durkin and Conti-Ramsden 2012). In higher education, the state of research on potential effects of online media usage on student achievement is inconclusive. Students' online information-seeking behaviour has not been observed to be directly related to student GPA, but an indirect effect via students' self-efficacy could be noted (Zhu et al. 2011). Similarly, certain Web-related information skills such as the critical evaluation of information found online seem to be associated with lower dropout intentions (Hillmert et al. 2017).

One reason why effects of online media on student achievement in higher education are limited could be that online media usage does not per se foster student learning, but only in particular forms of usage, primarily of information-related types and sources. For instance, neither students' access to computers nor their frequency of computer usage seems to affect their PISA mathematics achievement scores. Yet, for a subgroup of "autodidactic smart users", who possess above average computer skills which they have acquired on their own, the relation of computer usage to math achievement turns out to be positive (Wittwer and Senkbeil 2008). As for forms of usage, types of media also matter. In Durkin and Conti-Ramsden's (2012) study, only effects of educational, but not of recreational, online media usage on students' GCSE subject score were observed. Similarly, Gkorezis et al. (2017) noted that student online information-seeking is positively related to students' self-reported academic performance. Additionally, even social media usage might be beneficial for student learning if it is related to specific academic goals, but harmful if this relation is absent (Junco 2012).

Consequently, we argue that *qualitative* differences between undergraduates' online information sources are more decisive for individual achievement than differences between using online and traditional media per se. In particular, we propose to enrich research on information-seeking behaviour by the concept of *deep-level* vs. *surface-level student approaches to learning* (SAL; Marton and Säljö 1976) which is among the most powerful predictive concepts of academic success in higher education (Zeegers 2004). Within both the deep-level and the surface-level SAL, typical motives and strategies can be identified (Biggs 1987). The surface motive is characterised by an entirely instrumental view with its main objective of meeting the requirements with the least possible effort. Consequently, the surface strategy is limited towards usage of the bare essentials and routine methods. In the context of information behaviour within university, this may for example mean that students send one-word search queries to *Google* and click on links from the first page of results only. This is what we term surface-level or "basic" online search strategies. In contrast, the "deep" motive is characterised by students' intrinsic motivation with the overall objective of improving their achievement in specific academic subjects. As a result, the deep-level strategy is meaningful in terms of linking new knowledge to already existing knowledge (Biggs 1987).

There is plenty of empirical research that has linked SAL to academic achievement both in higher education and lower levels of education. Among the earliest studies, Biggs (1979) demonstrated that SAL may affect both quality and quantity of learning outcomes. A typical finding of later studies using more advanced statistical techniques is that the association between SAL and student achievement often disappears as soon as other correlates of student achievement have been controlled for. Yet, there is also evidence that SAL may predict student

achievement even after controlling for other correlates of achievement (e.g. Zhang 2000; Lizzio et al. 2002; Zeegers 2004; Trigwell et al. 2013). Most compelling, a meta-analysis by Richardson et al. (2012) indicates that deep-level learning styles are positively associated with GPA while its correlation with surface-level learning is negative.

Our specific contribution is to apply the distinction between deep- and surface-level learning approaches to students' online information-seeking behaviour in higher education. We assume that a deep or "advanced" search strategy manifests itself for example in using complex search queries and adapting search terms in response to the results of previous queries. Here, we focus on the platforms to which search queries are addressed. For instance, we classify the deliberate search for scholarly journals with peer-review procedures, which are hosted on platforms and databases specifically designed for this task, as "advanced". While the academic reputation of a source and the peer-review system are not infallible, the user may expect the information found there to be fairly reliable and therefore more likely to add to previous knowledge compared with information found with basic or surface-level strategies. In contrast, surface-level online information-seeking behaviour would imply that students send one-word search queries to *Google* and click on links from the first page of results only. Typical findings would include blog entries, statements on personal or commercial websites, etc. This is what we term surface-level or basic online search strategies.

In accordance with this state of research, we can formulate two hypotheses:

> *H_{1a}: Deep-level online information-seeking behaviour significantly improves student achievement in higher education.*
> *H_{1b}: Surface-level online information-seeking behaviour significantly attenuates student achievement in higher education.*

In addition to these two dimensions of online information-seeking behaviour, we also analyse effects of traditional (offline) information-seeking behaviour as a third dimension for which we do not expect any clear effects on student achievement.

The role of subject groups for informational learning environments

Another stream of research has focused on the role of students' learning environments for their study behaviour. Ramsden and Entwistle's (1981) study is supposed to be the first to demonstrate a relationship of learning environments to SAL. A short time later, Biggs (1985) presented a theoretical model on how situational factors such as subject area, teaching method, time on task, and task demands influence SAL. The most established association seems to occur between students' perception of heavy workload and a reproducing orientation or surface approach (e.g., Entwistle and Tait 1990; Ramsden 1991; Lizzio et al. 2002). Factors which are beneficial for students' development of a deep-level approach or meaning orientation have also been identified. Ramsden (1991) observed that students high in meaning orientation tend to perceive teaching content as particularly relevant, and they also see openness and good teaching in their learning environment. More recently, Karagiannopoulou and Milienos (2015) found that the deep approach is positively predicted by teaching for understanding and encouraging learning, and by integrative learning and critical thinking. In contrast, these predictors as well as congruence and coherence in course organisation were negatively related to the surface approach.

In addition, the structure of learning environments may differ between subject groups or departments. As Ramsden (1991) observed, the lowest scale levels of perceived good teaching,

clear goal setting, appropriate workload and assessment were found for the Health Sciences, while the same scores were highest for the Humanities and Arts, and for Education and the Social Sciences. Differences in learning environments may be consequential for the effectiveness of SAL: in Zhang's (2000) sample of Hong Kong tertiary students, the surface motive had positive effects on student achievement within the domains of Chemistry and Geography. Lizzio et al. (2002) observed a positive association between surface approach and GPA for business students. In van Lohuizen et al.'s (2009) study, the relationship between learning strategies and clinical performance of university hospital clerks was totally absent.

In sum, students' perceptions of their learning environments form particular beliefs about both department-specific and subject-specific demands and about successful strategies to meet those demands (Biggs 1985; Ramsden 1991; Brennan et al. 2010). While several studies explored whether SAL mediate the effect of learning environments on student achievement (e.g. Diseth 2007), our conclusion from subject-specific differences in the effectiveness of SAL on achievement is that this relation is *moderated* by learning environments.

Two important properties of learning environments that may influence students' perceived salience of which information-seeking strategies are most successful in their respective department are the degree of standardisation of knowledge during early stages of study programs (e.g., in text books) and differences in "publication culture". As a consequence of differences in the degree of standardisation of knowledge between fields (e.g. between "hard" and "soft" sciences), the benefits from using deep-level search strategies can be expected to vary by subject group. Surface-level search strategies might suffice for search tasks in more standardised environments but not in contexts of greater heterogeneity. Deep-level learning strategies are more beneficial when textbooks contain fewer uncontroversial facts and instead inform more about competing paradigms. More standardised knowledge can (but needs not necessarily) become manifest in more standardised academic tasks (e.g. multiple-choice exams in contrast to essays; cf. Scouller 1998). A review of the empirical literature by Baeten et al. (2010) indicates that students of the Humanities and the Social Sciences more frequently apply a deep-level approach to learning than students of Medicine, the Natural Sciences and also Business and Economics. In contrast, students from the latter subject groups more frequently adopt a surface-level approach than students of the Humanities.

We hold that this at least partly reflects the more standardised, more canonical and less controversial nature of knowledge that undergraduate students of the "hard sciences" are presented with during their first years. Catching up on the laws of thermodynamics in Physics or the central limit theorem in Statistics is probably more feasible using a surface-level approach to learning compared with topics in Sociology or Economics where there are fewer generally accepted laws. Note that current research in Physics or Medicine of course often includes controversies and competing paradigms which can hardly be grasped using one-word *Google* queries. Therefore, on the Master's or PhD level, assumptions regarding the learning environment would probably read differently. For the undergraduate level which we are focusing on here, however, we expect substantially smaller benefits or even harmful effects from using surface-level learning strategies in the Humanities and Social Sciences when preparing for exams or homework as compared with deep-level strategies, while in the Natural Sciences and in Medicine, surface-level strategies might well be beneficial.

Differences in publication culture might also be important for field-specific variation with regard to information behaviour. In the Humanities and Social Sciences, books continue to be an important academic source, while in other fields, findings are almost exclusively published in journals (Engels et al. 2012). This can partially be explained by the fact that in some

disciplines, foundational documents (mostly in the form of books) are often cited whereas in others, almost only current evidence is important (Hargens 2000). As a consequence, we expect field-specific differences regarding whether the relevant publications can mostly be found online, or (also) in libraries. Previous research finds that books or the library's online catalogue is more often consulted by students of "soft" disciplines (Whitmire 2002). Again, one needs to keep in mind that we are focusing on undergraduate students who usually do not learn about the forefront of current research but rather acquire the basics of the respective discipline. To this end, consulting the library is probably more effective in the Humanities and Social Sciences and less so in the Natural Sciences.

In sum, subject-specific differences of task standardisation and publication culture may affect the salience of information-seeking strategies across departments. Following the preceding state of research, we assume that deep-level online information-seeking behaviour is not only applied more often, but also yields higher achievement pay-offs in soft academic disciplines such as the Humanities and the Social Sciences. In contrast, usage of less sophisticated online information sources could suffice in more standardised learning environments such as undergraduate courses in Medicine or the Natural Sciences. Hence, our second set of hypotheses reads:

> *H_{2a}: The positive effect of deep-level online information-seeking behaviour on student achievement is moderated by students' learning environments. Strongest effects are expected in the subject groups of Humanities and Social Sciences.*
> *H_{2b}: The negative effect of surface-level online information-seeking behaviour on student achievement is moderated by students' learning environments. Weakest effects are expected in the subject groups of Medicine and the Natural Sciences.*

Conceptual framework

Figure 1 synthesises our conceptual arguments. We first assume that student achievement is positively influenced by deep-level online information-seeking behaviour (H_{1a}) and negatively

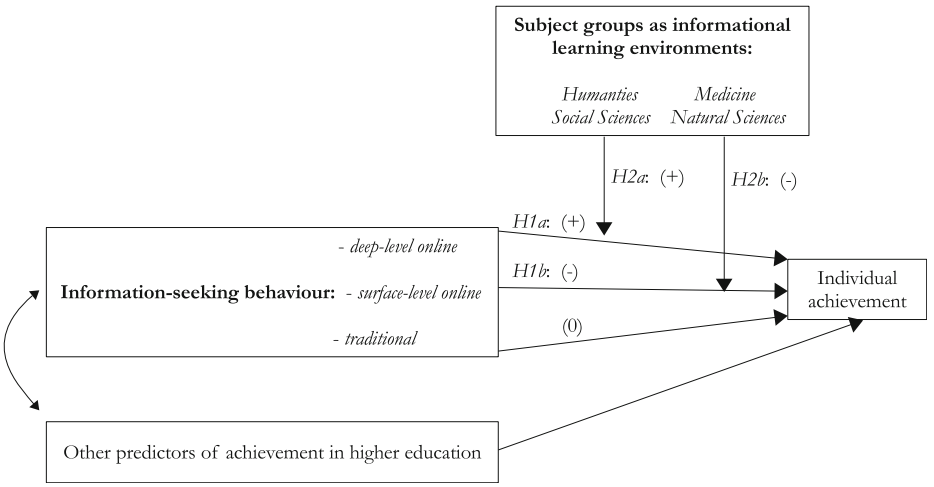

Fig. 1 Conceptual arguments

influenced by surface-level online information-seeking behaviour (H_{1b}). In contrast, we have no a priori assumptions concerning the returns of traditional information-seeking behaviour.

In addition, we postulate that the extent to which deep-level and surface-level information-seeking behaviour affect achievement depends on subject groups as specific informational learning environments. The positive effect of deep-level online information-seeking behaviour can be expected to be strongest for students of the Humanities and the Social Sciences, whereas the negative effect of surface-level information-seeking behaviour will be attenuated for students of Medicine and the Natural Sciences in particular.

Data and methods

Data

Our data come from a two-wave online survey among students at a large German university (Lang and Hillmert 2014, Burger 2015). The survey covered various aspects of university life, and its target groups were students from all academic fields. In the first wave, carried out in winter 2013/2014, 3816 respondents (14.4% of all students enrolled at the university at that time) participated. The follow-up survey took place in mid-2015 and had 769 participants. The net response rate for wave 2 was 39.2% if we take into account that only those who gave their permission after completing the first survey were contacted again. Most participants were undergraduate students, but all of them were at least in their 4th semester by the time of the second wave. Since we are interested in modelling the change in information behaviour and grades by taking past values into account, our sample consists only of participants of both waves.

As our outcome variable, we asked respondents to report the grades they received for their most recent exam and homework assignment. In the original German grading system used in most study programs, lower values represent better grades. We reverse-coded students' grades such that higher values refer to better grades, and we computed the arithmetic mean of all grades a student reported. A list of all variables in their original coding as well as descriptive statistics can be found in the Appendix Table 2.

Our main predictors of interest refer to the preparation of the work these grades were received for. Students were asked to name the sources they consulted when preparing their most recent graded assignment from a list of possible answers. As a first concept of information-seeking behaviour, going to the university's library and doing research there, or using the library's catalogue, were classified as "traditional" search strategies. Note, however, that traditional does not equal "offline", since modern libraries invest a large part of their resources into online functionalities. As a second factor, we refer to "basic online search strategies" if a student uses standard Internet search engines such as *Google* or consults *Wikipedia* when preparing a written assignment. We see these basic online search strategies as equivalent to the concept of surface-level learning strategies since they involve sending search queries to the most popular websites covering a broad range of sources of varying reliability without a specific filter for academic content.

By contrast, deep-level or "advanced online search strategies" go beyond these basic strategies and require some additional knowledge about where and how to find scientific content. As one indicator for advanced online search strategies, we consider the usage of search engines and platforms specifically designed to find articles in academic journals, e.g.

Google Scholar, *JSTOR*, *Web of Science* or *PubMed*. Using these platforms increases the probability of finding academically reliable content although many undergraduates are not familiar with them (Helms-Park et al. 2007). As a second indicator, we asked whether participants searched for English-language or other international sources when preparing their work. Introductory texts and materials at German universities are often in German language while the most recent and most relevant publications on a topic come from a much broader spectrum of sources, in particular sources in English language. As a consequence, using English search queries or consulting international journals can be seen as an indicator of a more sophisticated search strategy compared with relying exclusively on German-language content. Confirmatory factor analysis supports our classification of these three factors comprising two items each. Using *Mplus* 7 (Muthén and Muthén 2012), we calculated factor scores for each individual, analysing both waves separately.

We group study majors into four subject groups: (a) Language and Cultural Studies, (b) Mathematics and Natural Sciences, (c) Law, Economics, and Social Sciences, and (d) Medicine. Each of these aggregations is still heterogeneous with regard to the study courses it encompasses, but the differences between the four groups are arguably large enough to test for moderating effects. Knowledge about academic standards can be expected to increase with time spent at university, which is why we control for the number of semesters the respective respondent has been enrolled in the current study course. As an indicator of general educational ability, students were asked to provide the grade point average from their high school diploma (German *Abitur*). We also include reported preparation time in hours (measuring effort) as a control variable as this can influence both information behaviour and academic outcomes. Moreover, from a social networks perspective, learning with peers can affect performance. We therefore asked how often respondents met with co-students for the purpose of learning in the past 4 weeks. In addition, respondents were asked to think of up to three peers they meet most frequently for learning, and to assess the academic performance of these relative to their own (on a five-point scale ranging from "much worse" to "much better than my own performance"). Students' gender and their parents' level of education are included as well. The latter is operationalised as the number of parents with tertiary education (0 to 2). In addition, ethnic minority status is measured using the concept of migration background, i.e. as a binary variable denoting if the respondent or at least one of his/her parents was born abroad.

Methods of analysis

We use several statistical models to account for the longitudinal structure of our data. We start with ordinary least squares (OLS) regressions where grades are estimated as a function of search strategies. In these models, both the dependent as well as the independent variable of interest are measured at wave 2. Here, we calculate the partial correlations between the usage of traditional, basic, and advanced online search strategies, respectively, and grades. We start with a model without any other covariates and add control variables in a second model.

Next, we introduce a lagged dependent variable into the model, i.e. grades the respondent had reported during the first survey wave (model 3). The intention here is to capture unobserved heterogeneity between individuals that can for example result from specific study programs giving systematically better grades than others. As a different approach to tackling unobserved heterogeneity, we change our dependent variable to the change in grades between the first and the second wave (model 4). Using differenced values instead of levels eliminates all variance due to unobserved constant factors that lead to the differences in the first place.

Grades at $t = 1$ are included as a predictor in the model since a negative correlation between lagged grades and change in grades can be expected due to a "ceiling effect" or so-called regression to the mean: if a student received the very best grades at time $t = 1$, it is likely that the subsequent grades will be worse (at least they cannot be better), and vice versa.

As another model specification (model 5), we test whether information behaviour at $t = 1$ influences subsequent improvement in grades between $t = 1$ and $t = 2$, controlling for current grades. The idea here is to tackle the issue of endogeneity (or direction of causality): are grades influenced by search behaviour, as we posit, or is sophisticated search behaviour simply an indicator or outcome of high academic performance? Since in model 5, we measure search strategies at $t = 1$, they cannot be influenced by the dependent variable, which is again the change in grades between wave 1 and wave 2. We can therefore rule out the issue of reverse causality. Finally, we employ a first-differenced estimator (model 6) where both dependent and independent variables are measured in terms of change rather than level. For instance, if a student increases their usage of academic journals and international sources, do we usually see an improvement in grades over the observed period? Using both a lagged dependent variable as well as a first-differenced model, we can investigate whether the initial level of search skills determines the future path (model 5) or whether improvements in the sophistication in search strategies pay off at any level (model 6).

Finally, we carry out split-sample analyses with regard to broad discipline (subject group). Regression analyses as in model 2 are separately estimated for the four subject groups to explore whether the impact of information behaviour differs by field of study. For all analyses, missing data were multiply imputed. Each model was separately estimated in ten multiply imputed datasets and the results were averaged. Statistical analyses were carried out with base *R* (R Core Team 2017) except for the confirmatory factor analysis of information behaviour which was estimated with *Mplus*.

Results

Descriptive results

Figure 2 displays percentage values for the share of respondents' reported usage of the six sources representing our three factors of information behaviour: traditional search strategies (upper two panels), basic online search strategies (*Google* and *Wikipedia*), and advanced online search strategies (bottom panels). Values are differentiated by broad discipline (subject group) and time (wave 1 and 2). The error bars depict 95% confidence intervals as an indicator of uncertainty given varying case numbers in each subject group (see Appendix Table 2 for details).

There are two important insights from this descriptive analysis. First, notable differences between subject groups become apparent. As indicated by previous research, students of Humanities and Social Sciences went significantly more often to the library or consulted the library's catalogue compared with students of Mathematics, Natural Sciences, and Medicine. By contrast, the latter groups used *Wikipedia* much more frequently. This is in accordance with our assumptions that in the "hard" sciences, knowledge in undergraduate teaching is more standardised and basic or surface-level search strategies can suffice in finding the desired information with an acceptable level of reliability. Among all disciplines, most students use *Google*. With regard to academic journals and international sources, differences between

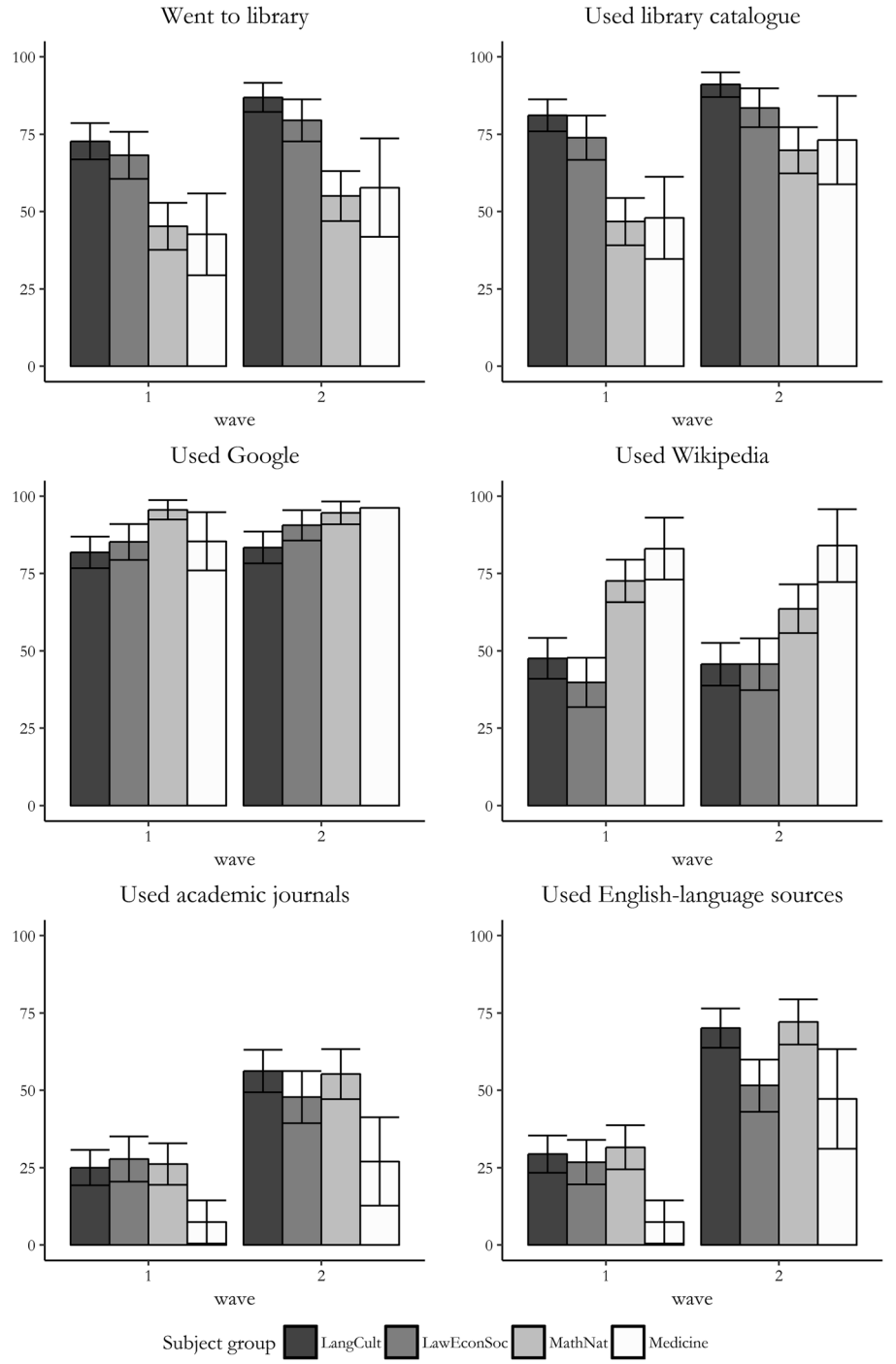

Fig. 2 Percentage values for the share of respondents' reported usage of the six sources representing our three factors of information behaviour: traditional search strategies (upper two panels), basic online search strategies (Google and Wikipedia), and advanced online search strategies (bottom panels)

subject groups are generally small, but students of Medicine seem to consult these sources less frequently compared with the other groups.

A second important insight concerns the relation between basic and advanced search strategies. As the graphs suggest, advanced search strategies are not a substitute for, but rather a complement to basic strategies. The same is true regarding the distinction between online and offline search. Students who go to the library also predominantly use *Google*. Regarding the search for journals and international sources, a clear upward trend can be noted. At the time of the first wave of the survey, the majority of participants were in their first year of study. Among those who already prepared a paper or other written assignment, only around 25% of students searched for journal articles or international sources, respectively. Over the course of time, it can be assumed that more students became familiar with academic customs and the importance

Table 1 Determinants of students' grades (OLS regressions)

	Dependent variable:					
	Grades in wave 2			Delta (grades)		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−.031	−.047	−.009	−.009	−.012	−.004
	(.040)	(.038)	(.043)	(.043)	(.046)	(.044)
Grades (in wave 1)			.165**	−.835***	−.807***	−.835***
			(.055)	(.055)	(.060)	(.058)
Traditional search strategies	−.136*	−.104	−.095	−.095		
	(.063)	(.063)	(.064)	(.064)		
Basic online search	−.034	−.078	−.071	−.071		
	(.058)	(.054)	(.054)	(.054)		
Advanced online search	.341***	.299***	.286***	.286***		
	(.048)	(.049)	(.050)	(.050)		
Traditional search (wave 1)					−.021	
					(.074)	
Basic online search (wave 1)					.032	
					(.063)	
Advanced online search (wave 1)					.213***	
					(.059)	
Delta (traditional search)						−.075
						(.048)
Delta (basic online search)						.052
						(.054)
Delta (advanced online search)						.156**
						(.057)
Subject group: Mathematics and Natural Sciences		−.074	−.067	−.067	−.076	−.059
		(.043)	(.044)	(.044)	(.049)	(.047)
Subject group: Law, Economics, Social Sciences		−.254***	−.211***	−.211***	−.210***	−.199***
		(.041)	(.045)	(.045)	(.046)	(.045)
Subject group: Medicine		−.101	−.109	−.109	−.159**	−.141*
		(.056)	(.058)	(.058)	(.060)	(.058)
Control variables:	No	Yes	Yes	Yes	Yes	Yes
Observations	662	662	662	662	688	662
Adjusted R^2	.071	.244	.303	.558	.551	.579

Cells show regression coefficients and standard errors in brackets. For coding of variables and controls, see section on methods text. Reference for subject groups: Language and Cultural Studies. Data source: Burger (2015). *$p < .05$, **$p < .01$, ***$p < .001$

of English-language publications, such that at the time of the second wave, around half of all participants had used databases or search engines designed to find peer-reviewed journals.

As the data show, the increase in advanced search strategies was not accompanied by a decrease in *Wikipedia* or *Google* usage. Library and catalogue use also remained constant or increased in all groups. This means that students typically do not stop consulting *Google* or *Wikipedia* after they start using platforms such as *Google Scholar*, *Web of Science* or *PubMed*. On the individual level, the analysis suggests that the move towards advanced search strategies can be conceived as a learning process. All our respondents who already used academic and/or international sources in the first wave continued to do so in the second wave, i.e. no one went back to using only *Wikipedia* or *Google*. We also find that (physically) going to the library is still important and does not lose significance over time.

Multivariate analyses

How effective are these different search strategies for grades? Table 1 presents the results from OLS regressions using six different modelling approaches, as described in the section on methods. In model 1, we regress grades obtained for recent exams and written assignments on factor scores representing the three types of search strategies. Advanced search strategies, i.e. usage of academic search engines and databases as well as international search queries, are associated with better grades, while there is a negative and significant effect for traditional search strategies. The latter vanishes, however, once we control for field of study (subject groups) as well as a set of other control variables including gender, study progress, workload, and learning partners' performance. These variables are not shown in Table 1 for reasons of space, but a complete effect plot for model 2 is given in the Appendix 1. Among the control variables, high school diploma results (university entrance grade average, in German *Abiturnote*) are positively correlated with grades, meaning that better high school students have on average better grades in college. Learning with high-achieving partners is also positively associated with grades. Among the disciplines, the group of Law, Economics and Social Sciences receives on average lower grades, possibly indicating that grading is stricter in these fields. Note that all continuous variables have been standardised to a mean of 0 and a standard deviation of 1 in order to make the effect sizes comparable in the plot. Basic search strategies, i.e. usage of *Google* or *Wikipedia*, are not significantly correlated with grades.

The impact of advanced search strategies on grades remains positive and substantially large even after controlling for the various other factors in the models. This is also true when we include the lagged dependent variable, i.e. grades received at the time of the previous survey wave (model 3). This means that if previous performance is held constant, more sophisticated search strategies translate into better grades at $t = 2$. Effects remain constant if the dependent variable measures the change in grades instead of the level (model 4). Using advanced search strategies thus leads to an improvement in grades. In models 4 to 6, the effect of the lagged dependent variable is strongly negative, which is not surprising since getting the very best grades in wave 1 can only be followed by stability or decrease. Using advanced search strategies in wave 1 usually entails an improvement in grades between waves 1 and 2 (model 5). Finally, in the first-differenced model (6), changes in advanced search strategies are positively associated with changes in grades.

Given the persistence of positive and significant effects from advanced search strategies throughout all model specifications, we conclude that there is strong

evidence in favour of our hypothesis H1a: adopting advanced or deep-level search strategies usually leads to better grades. In contrast to hypothesis H1b, basic (or surface-level) online search strategies are not significantly correlated with achievement. This possibly indicates that both high-performing and low-performing students use *Google* and *Wikipedia*, and the crucial question apparently is whether students use more sophisticated searches in addition.

Theoretical considerations as well as the descriptive findings from our survey suggest that effects from search strategies on grades may not be uniform across all disciplines. In our data, we can distinguish four subject groups with sufficient sample sizes. We perform the analysis as in model 2 of Table 2 separately within each group. Figure 3 displays the effect of traditional search strategies on grades for each subject group. As the results suggest, doing research in the library and consulting the library's catalogue is associated with better grades in the field of Language and Cultural Studies. A possible explanation could be that in these disciplines, the importance of books (such as foundational works in Philosophy) relative to the latest journal articles or conference proceedings is arguably greater compared with other fields. By contrast, the slope of the regression line is negative in the three other groups, though only significant in the group of Law, Economics and Social Sciences. This could mean that in this subject group, higher-achieving students rely on sources other than the library.

As Fig. 4 shows, basic online search strategies are usually not significantly associated with grades in most disciplines. Only in Medicine can using *Google* or *Wikipedia* be associated with better grades. Interpreting this finding, one first has to note that the vast majority of all students use surface-level search strategies, and more sophisticated strategies are usually a supplement rather than a replacement for *Google*

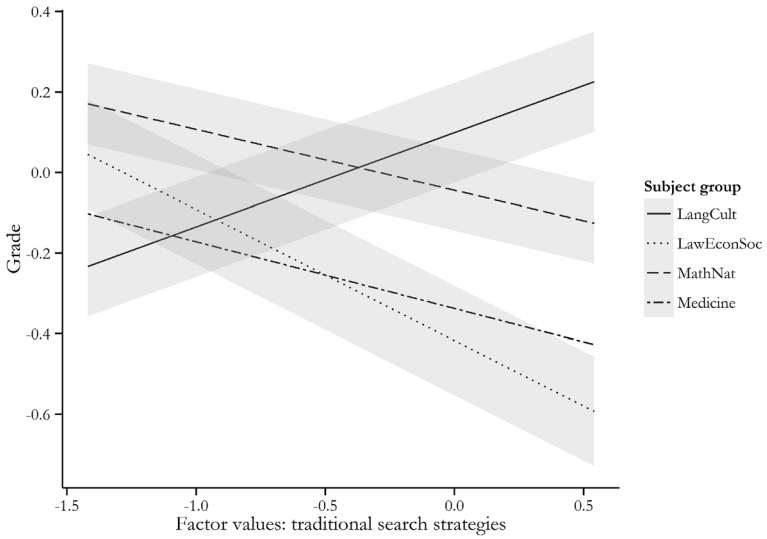

Fig. 3 Predicted values for grades as a function of traditional search strategies, by subject group

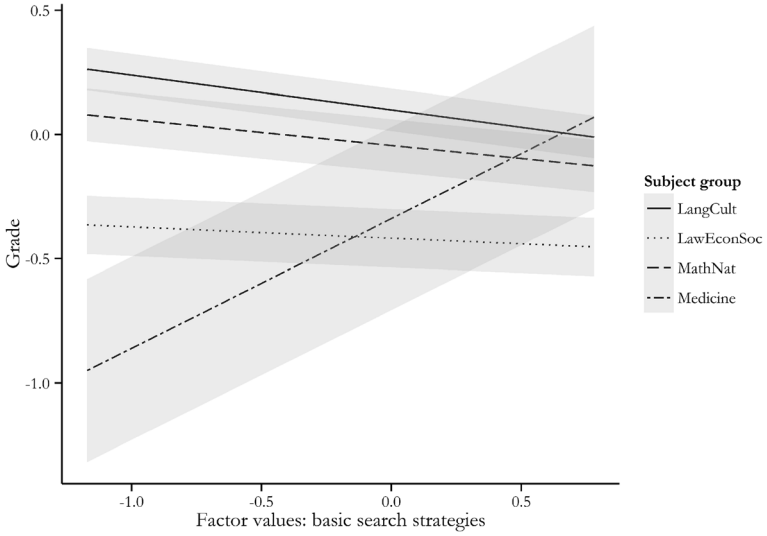

Fig. 4 Predicted values for grades as a function of basic online search strategies, by subject group

and *Wikipedia*. It is thus in line with our theoretical expectations that for most subjects, basic online search strategies do not harm but also do not contribute to better grades. Medicine is an exception, possibly because medical undergraduates in our sample are by far the least likely to use academic journals or English-language sources when preparing for exams (see Fig. 2). The few medical students who were *not* consulting *Google* or *Wikipedia* were either solely relying on offline information which, other than in the Humanities, is not associated with better grades—or were not using any of these sources.

While most students use *Google* or *Wikipedia*, it is the consultation of databases or search engines specifically designed to find academic content and international sources that can separate low-achieving from high-achieving students. This is true in all fields, as Fig. 5 shows. However, the highest return from adopting advanced online search strategies (in terms of grades) appears to be attainable in the fields of Mathematics and Natural Sciences.

Discussion

The goal of this paper has been to evaluate the impact of online search strategies on academic achievement. As a theoretical contribution to the literature on information-seeking in higher education, we build on the distinction between deep-level and surface-level learning in educational psychology and derive the concepts of "basic online" and "advanced online" search strategies, contrasted with traditional search strategies. Our theoretical expectations have been that students who consult databases and search engines designed to find academic content in peer-reviewed journals, and use English-language search queries, tend to be more successful in terms of grades.

So far, most evidence on the importance of search strategies for academic achievement has come from small experimental studies or cross-sectional surveys. We have

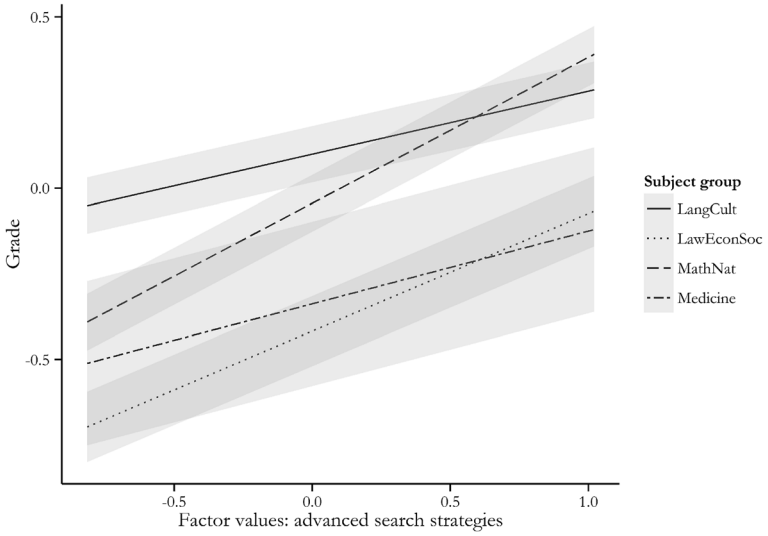

Fig. 5 Predicted values for grades as a function of advanced online search strategies, by subject group

compiled data from a two-wave panel study among undergraduate students from various disciplines to study how information behaviour and academic achievement develop over time and how the two factors are related to one another. This has allowed us to address critical methodological issues such as reverse causality or unobserved heterogeneity that have made it difficult to attribute good grades to sophisticated information behaviour in previous research.

Our data confirm that the distinction between surface-level (or basic) and deep-level (or advanced) search strategies is indeed useful for higher education research. An important insight is that advanced search strategies do not replace but rather complement basic search strategies which are still used by advanced learners. In line with our theoretical expectations, we find that advanced search strategies have a robust and positive effect on academic achievement. By contrast, basic as well as traditional search strategies show no significant impact on grades across disciplines. A possible explanation can be the aforementioned finding that advanced students still use surface-level strategies and the crucial question is whether deep-level techniques are applied in addition.

As expected, we also find evidence of an interaction between individual behaviour and the organisational context, as indicated by a few notable differences between disciplines. Traditional information behaviour is associated with lower achievement especially in Law, Economics and Social Sciences, but with better grades in Language and Cultural Studies. Yet, we find positive effects of advanced search behaviour in all disciplines. Following previous research, we expected this effect to be strongest in the Humanities, but in the data we found even stronger benefits for students of Natural Sciences. This finding might be pointing to the disciplines' publication culture, with a strong emphasis on international, peer-reviewed journals already factoring in for undergraduates.

Conclusion

The Internet has become ubiquitous in university life. However, previous research has indicated that students typically enter university with insufficient information literacy skills. Such skills are increasingly demanded as they are necessary to critically evaluate the academic quality and reliability of content found online. In this paper, we focus on the search process that students go through when looking up content online in order to prepare for exams or homework. It is useful to distinguish basic online search strategies, i.e. simple queries to well-known search engines or online knowledge bases, from advanced approaches requiring more sophistication. Multivariate analyses provide strong evidence for the hypothesis that advanced online search strategies are associated with better grades in all fields of study. In the Natural Sciences, the benefits from searching for journal articles and international sources appear to be highest. In Languages and Cultural Studies, doing research in the library is still vital for academic success.

There are several limitations to this analysis with regard to measurement and the structure of the data. For instance, we have to rely on reported behaviour and grades which we cannot verify. Moreover, we do not assess how often (and how intensively) students use the respective strategies. Other studies have looked at actual search behaviour in greater detail (e.g. Weber et al. 2018), but at the cost of a much lower sample size. The mechanisms linking deep-level search strategies and academic outcomes need further investigation. We have looked at grades in this paper. In this case, citing specific sources might also signal to teachers a compliance with academic norms and conventions. Future research might investigate the specific role of information behaviour for learning outcomes. Finally, long-term effects of information behaviour could not be assessed with the data at hand. The subject-specific effects found in this study might differ on the Master's or PhD student level.

Our study highlights the importance for students to familiarise themselves with online search techniques that go beyond standard *Google* searches or *Wikipedia* consultations. Undergraduate students are often not aware of academic conventions such as the peer-review system and sources of information such as scholarly journals, academic databases and search engines that can help to find and access academic content. In addition, many students may search for information in their native language only so that they are likely to miss out on the most relevant publications, particularly in non-English-speaking contexts. Our findings suggest that communicating these strategies to students early during the course of their studies can be an effective means to improve academic performance. In all disciplines, knowing where and how to find sources of recognised academic reputation is of crucial importance. This requirement can be expected to grow in salience as more and more academically relevant content can be found online.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix 1

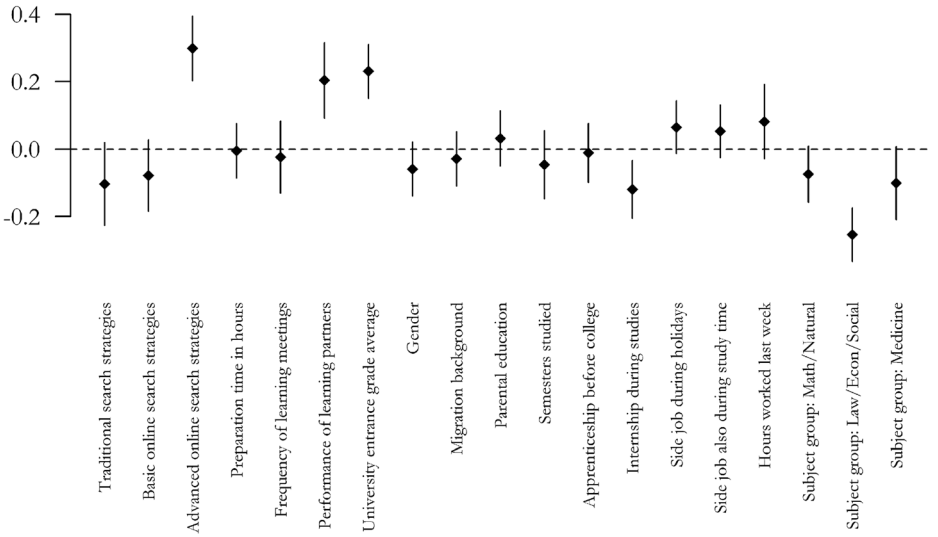

Fig. 6 Effects on grades for exams and papers (cf. Table, model 2)

Appendix 2

Table 2 Overview of the data and variables used in the study

Variable	Definition	Valid *N*	Mean	Standard deviation	Min	Max
Journals	For my last written assignment I… …searched for articles published in scientific journals using platforms such as JSTOR, Google Scholar, Web of Science, or Pubmed.	541	0.523	0.500	0	1
Journals_t1	…searched for journal articles (wave 1).	605	0.246	0.431	0	1
IntSources	…searched for English-language or other international sources.	525	0.648	0.478	0	1
IntSources_t1	…searched for English-language or other international sources (wave 1).	596	0.277	0.448	0	1
Wikipedia	…consulted Wikipedia.	500	0.524	0.500	0	1
Wikipedia_t1	…consulted Wikipedia (wave 1).	451	0.579	0.494	0	1
Google	…used Google or other online search engine.	501	0.892	0.310	0	1
Google_t1	…used Google or other online search engine (wave 1).	454	0.872	0.334	0	1
Library	…went to the university library (or the institute's library).	501	0.747	0.435	0	1
Library_t1	…went to the university library (or the institute's library) (wave 1).	453	0.598	0.491	0	1

Table 2 (continued)

Variable	Definition	Valid *N*	Mean	Standard deviation	Min	Max
Catalogue	…used the library's online catalogue or database.	501	0.830	0.376	0	1
Catalogue_t1	…used the library's online catalogue or database (wave 1).	453	0.649	0.478	0	1
LangCult	Major subject belongs to subject group of Language and Cultural Studies as defined by the German Statistical Office (253 students in this group)	706	0.358	0.480	0	1
LawEconSoc	Major subject belongs to subject group of Law, Economics, and Social Sciences (157 students in this group)	706	0.222	0.416	0	1
MathNat	Major subject belongs to subject group of Mathematics and Natural Sciences (191 students in this group)	706	0.271	0.445	0	1
Med	Major subject belongs to subject group of Medicine (79 students in this group)	706	0.112	0.315	0	1
Group_other	Major subject belongs to other subject group (26 students)	706	0.037	0.188	0	1
Sidejob_none	Respondent has no side job besides their studies	706	0.323	0.468	0	1
Sidejob_vacation	Respondent works at a side job in semester break	706	0.127	0.334	0	1
Sidejob_always	Respondents always works at a side job besides their studies	706	0.445	0.497	0	1
LearningMeetings	Number of meetings with other students for the purpose of learning in past 4 weeks	362	2.177	2.000	0	12
PartnerGrades	Performance of up to three most frequent learning partners (mean value) compared to own grades, participant's perception (1 = much worse than me, 5 = much better than me)	336	2.819	0.702	1.000	4.667
Grades	Grades received for last exam and paper (mean value, 1 = best, 5 = worst)	586	1.902	0.756	1.000	5.000
UED	University entrance diploma (grade average when leaving high school, lower values are better)	686	2.008	0.603	1.000	4.200
Gender	0 = Male, 1 = Female	706	0.677	0.468	0	1
Apprenticeship	Participant has completed an apprenticeship/ vocational training before entering college (0 = No, 1 = Yes)	706	0.085	0.279	0	1
Migration Background	0 = Respondent and both parents were born in Germany, 1 = At least one was born abroad	694	0.182	0.386	0	1
ParentsAcademics	Number of parents having tertiary education	592	0.855	0.814	0	2
Semester	Number of semesters participant has been enrolled in current	693	3.973	3.312	1	27

Table 2 (continued)

Variable	Definition	Valid *N*	Mean	Standard deviation	Min	Max
	degree course at time of second wave of survey					
HoursPrepared	Number of hours devoted to preparing for university last week	636	13.178	12.004	0.000	72.000
Internship	Already completed an internship during current course of studies (0 = No, 1 = Yes)	706	0.601	0.490	0	1
WorkingHours	Number of hours worked for side job(s), last week	311	11.592	10.117	0	60
Grades_t1	Grades received for last exam and paper at first wave (mean value, 1 = best, 5 = worst)	390	1.946	0.925	1.000	5.000
Factor_ advanced_t1	Factor score: advanced search strategies (journals, international sources) at first wave	688	0.054	0.761	− 0.550	1.594
Factor_ traditional_t1	Factor score: traditional search strategies (library, catalogue) at first wave	688	− 0.017	0.663	− 1.315	0.851
Factor_basic_t1	Factor score: basic online search strategies (Google, Wikipedia) at first wave	688	0.002	0.634	− 1.257	0.778
Factor_ advanced_t2	Factor score: advanced search strategies (journals, international sources) at second wave	662	0.024	0.828	− 0.815	1.021
Factor_ traditional_t2	Factor score: traditional search strategies (library, catalogue) at second wave	662	0.001	0.620	− 1.420	0.541
Factor_basic_t2	Factor score: basic online search strategies (Google, Wikipedia) at second wave	662	− 0.002	0.680	−1.172	0.781

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