

How Information Literate Are Junior and Senior Class Biology Students?

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Abstract Information literacy—i.e. obtaining, evaluating and using information—is a key element of scientific literacy. However, students are frequently equipped with poor information literacy skills—even at university level—as information literacy is often not explicitly taught in schools. Little is known about students’ information skills in science at junior and senior class level, and about teachers’ competences in dealing with information literacy in science class. This study examines the information literacy of Austrian 8th, 10th and 12th grade students. Information literacy is important for science education in Austria, because it is listed as a basic competence in Austria’s science standards. Two different aspects of information literacy are examined: obtaining information and extracting information from texts. An additional research focus of this study is teachers’ competences in diagnosing information skills. The results reveal that students mostly rely on online sources for obtaining information. However, they also use books and consult with people they trust. The younger the students, the more they rely on personal sources. Students’ abilities to evaluate sources are poor, especially among younger students. Although teachers claim to use information research in class, their ability to assess their students’ information competences is limited.

Keywords Information literacy · Competences · Obtaining information · Biology teaching

Introduction

The role of information in society has changed rapidly in recent decades. Information is no longer seen as knowledge owned by individuals, but increasingly gains a global dimension in today’s international information society (Webster, 2014). Information and communication technology (ICT) has transformed the world in which students grow up and learn. While 30 years ago, locating information from separate sources, locations, persons, or channels was

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challenging, information is now easy to locate and review, even on mobile devices such as tablet computers or smartphones (Case and Given 2016; Castek and Beach 2013). In addition, students are well equipped with ICT. As demonstrated by the PISA results, 96% of students in OECD countries report to have at least one computer at home. Ninety-three percent of these students also have Internet access. In addition to students' private access to ICT, schools are also investing in ICT. In OECD countries, on average, 4.7 students share one computer (desktop, laptop or tablet computer) at school, with 72% reporting regular use of such devices in a classroom setting (OECD 2015). In science, about one fifth of all students use ICT in most or all of their lessons. This is less often than in computer science but more often than in language classes (Fraillon et al. 2014). The problem for modern-day students is therefore not the accessibility of information, but rather the management and critical evaluation of information, which often is conflicting, outdated or simply incorrect (Case and Given 2016; Emery et al. 2015). Teachers are responsible for educating today's 'connected' learners to become critical consumers of information, helping them to make informed choices and to avoid harmful behaviours. Teachers are therefore faced with new challenging issues from information overload to plagiarism or threats to privacy (OECD 2015). These issues are not the exclusive domain of computer science lessons, but are relevant for all subjects, as they are all affected by changes in information practices in equal measure.

With information competences having become increasingly important in recent years, a number of countries have released standards for information literacy. As the American Library Association (ALA 1989, p. 1) defines it: 'To be information literate, a person must be able to recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information.' Similar standards for information literacy are in force in several countries, although the focus shifts between different countries. In the USA and Great Britain, information literacy is understood as information technology, where the emphasis is placed upon locating and evaluating sources of information (Johnston and Webber 2003; Snaveley and Cooper 1997). By contrast, the use of information is at the centre of interest in Australia (Bundy 2004). In accordance with the different priorities, competences representing information literacy standards can be determined (Table 1).

Especially when information literacy is equated with information technology, research often focuses on information literacy as a skill that is transferable across disciplines and applications. Against this backdrop, Mutch (1997) expresses concern about the alarming separation of information literacy from content knowledge. Although information selection and processing skills can be used in different contexts, information literacy also partly depends on context-specific knowledge (Catts 2010).

Information literacy depends on general information management skills as well as on domain-specific knowledge. In contrast to less experienced individuals, people who are experienced in searching the web for information are more successful at locating adequate sources, need less time doing so, use more elaborate strategies for their queries, and are able to flexibly reformulate the problem in order to maximise their chances of success (Chevalier et al. 2015; Sanchiz et al. 2017; Tabatabai and Shore 2005). As far as domain-specific knowledge is concerned, high scores on prior knowledge in the domain as well as sophisticated epistemic beliefs have a positive effect on information literacy skills (Khosrowjerdi and Iranshahi 2011; Monchoux et al. 2015; Rosman et al. 2016). As meaningful learning occurs in an active process of constructing conceptual relations between prior and new knowledge, knowing about general rules of information processing is insufficient (Glynn and Muth 1994). Accordingly, Grafstein (2002; p. 202) argues in favour of information literacy being part of subject-

Table 1 Information literacy standards in different countries

Great Britain (SCONUL 2011, p. 5)	USA (ACRL 2006)	Australia and New Zealand (Bundy 2004; p. 12)	Germany (Danmenberg 2002; p. 314)
Able to identify a personal need for information	The information literate student... ...defines and articulates the need for information.	The information literate person... ...recognises the need for information and determines the nature and extent of the information needed.	Identify and describe the need for information
Can assess current knowledge and identify gaps	...accesses the required information effectively and efficiently.	...finds the required information effectively and efficiently.	Locate adequate information
Can construct strategies for locating information and data	...evaluates information and its sources critically and incorporates selected information into his or her knowledge base and value system.	...critically evaluates information and the information-seeking process.	Evaluate information, sources and search processes
Can locate and access the information and data they need	...uses information effectively, individually or as a member of a group, to accomplish a specific purpose.	...manages information collected or generated.	Use and present information
Can review the research process and compare and evaluate information and data	...understands many of the economic, legal, and social issues surrounding the use of information, and accesses and uses information ethically and legally.	...applies prior and new information to construct new concepts or create new insights.	
Can organise information professionally and ethically		...understands and acknowledges cultural, ethical, economic, legal, and social issues surrounding the use of information.	
Can apply the knowledge gained			

related education in order to foster skills ‘that are embedded within research paradigms and procedures of disciplines’.

Information Literacy and Science

Creativity, communication, collaboration and critical thinking are known as the 4Cs students should master in order to function successfully in the twenty-first century. The use of information and communication technologies is fundamental for developing these skills (Keane et al. 2016). There is vivid debate on the extent to which the development of these skills can be integrated into the science curriculum. Opinions range from integrating the whole concept of science media education into science teaching (which includes the use of media as sources for science education, as well as the critical evaluation of any media by understanding the socio-cultural and socio-economic context) to teaching critical information literacy (a concept which relies on the application of critical thinking to information and its sources) (Reid and Norris 2016; Storksdieck 2016). As knowledge in science is mainly derived from empirical sources, the ability to decode the content and accuracy of scientific data presented in various sources is essential for gaining knowledge (Bromme and Goldman 2014; Majetic and Pellegrino 2014). But the critical use of information depends on the background knowledge students have. Anderman et al. (2012) therefore argue in favour of building sufficient content knowledge as a basis for further information acquisition. Podgornik et al. (2017) examined the connection between information literacy and scientific literacy in university students. They report a moderate correlation of information literacy and science literacy, with students who demonstrated better scientific understanding also scoring better at cognitive levels of information literacy and in the application of science knowledge.

With regard to science education, information literacy is included in different national standards. The New Generation Science Standards (NGSS) for K12 education in the USA, for instance, list ‘obtaining, evaluating and communicating information’ as one of eight standards for science and technology (NRC 2012). This standard also names relevant competences for different grades in secondary education (Table 2).

Table 2 Competences for ‘obtaining, evaluating and communicating information’ in the New Generation Science Standards (NRC 2014, p. 11)

Grades 6–8	Grades 9–10	Grades 11–12
Gather relevant information from multiple print and digital sources	Gather relevant information from multiple authoritative print and digital sources	Gather relevant information from multiple authoritative print and digital sources
Use search terms effectively	Use advanced searches effectively	Use advanced searches effectively
Assess the credibility and accuracy of each source	Assess the usefulness of each source in answering the research question	Assess the strengths and limitations of each source in terms of the specific task, purpose and audience
Quote or paraphrase the data and conclusions of others	Integrate information into the text selectively to maintain the flow of ideas	Integrate information into the text selectively to maintain the flow of ideas
Avoid plagiarism	Avoid plagiarism	Avoid plagiarism and overreliance on any one source
Follow a standard format for citation	Follow a standard format for citation	Follow a standard format for citation

Table 3 Information literacy standards and its levels in Austrian science standards (Schiffl 2017)

	Obtaining information	Extracting information
Level 1	Naming appropriate information sources	Extracting information from everyday texts
Level 2	Naming appropriate information sources and knowing how to obtain them	Extracting information from simple school and subject-related texts (for example, from junior class text books)
Level 3	Naming appropriate information sources, knowing how to obtain them and being able to name evaluation criteria for different sources	Extracting information from difficult school and subject-related texts (for example, from senior class text books)
Level 4	Naming appropriate information sources, knowing how to obtain them, being able to name evaluation criteria for different sources and obtain sources	Extracting information from scientific papers

Apart from this special information literacy competence in science, the literacy concept can be integrated into various other NGSS competences (NRC 2014).

Outside of the USA, information literacy also plays an important role in the science standards of German-speaking countries. In Germany, for example, information literacy is included in ‘communication’, which is one of four areas of competence in the German standards model for lower secondary education, where communication is defined as ‘obtaining and exchanging information appropriately and professionally’ (KMK 2005, p. 7). Unlike the competence areas of ‘content knowledge’ and ‘enquiry’, no detailed specifications have been provided to date. In Switzerland, ‘develop[ing] information’ is one of eight competency areas. It includes four aspects of information literacy: distinguishing sources of information, extracting information, information research and evaluating sources and information (EDK 2011, p. 6). In the Austrian competency model for science, information literacy can be found in ‘organising knowledge’, where ‘extracting information from different sources’ is requested (BIFIE 2011, p. 2). This competence is divided into obtaining and extracting information, for both of which levels of competence are stated (Table 3).

According to Austrian science standards, literacy is the process of obtaining information—especially naming and evaluating sources—and extracting information from biological texts. While these are relevant skills for secondary school students, there has so far been little research on the levels of information literacy among this population. But the facts that Austrian students score below the OECD average in PISA and that 23% of students belong to the ‘high-risk group’ for reading suggest that Austrian students may have difficulty extracting information (OECD 2016). The first aim of the current study is to examine different levels of information literacy in Austrian students of different class levels.

In addition to the standards debate, information literacy plays a crucial role in modern science teaching, as teacher-centred methods are substituted by student-centred approaches. When information is not presented by the teacher—as is the case with different approaches such as enquiry-based or problem-based teaching—students have to obtain appropriate sources and extract information themselves (Carder et al. 2001; Dochy et al. 2003; Hepworth and Walton 2009; Hmelo-Silver 2004; Owens et al. 2002).

Students’ Information Literacy

Although information literacy is equally crucial for secondary science education, most research in this field is limited to higher education settings (Grafstein 2002; Klucevsek and Brungard

2016; Maybee 2006). This is problematic, as different standards would apply to younger students than to students at university level. The use of primary sources such as peer-reviewed journals, for example, is an important topic in late secondary education and at university level. More junior students, however, lack the necessary knowledge for understanding primary sources and therefore have to learn how to work with secondary content (Samson, 2010). In the context of secondary education, Van Deursen and Van Diepen (2013) doubt that students possess sufficient information and strategic skills for using the Internet for homework and school projects, because they display deficiencies in defining search queries and evaluating information. But even students at university level often lack sufficient skills for conducting appropriate academic searches (Lanning and Mallek 2017). Compared to the ACRL standards for higher education (ACRL 2006), even university students show poor performance, especially on standard two, which deals with accessing information (Smith et al. 2013).

Older studies in the field of information literacy focus on which information sources students use for their queries. Brown (1999), for example, examined information literacy in physics graduates, using a questionnaire on the subject of information research. She found that over 70% of students used a similar approach to searching for information, which predominantly focused on online data. Thirty-six percent of students also reported seeking advice from human resources such as professors or fellow graduate students in searching for information. Based on these results, Brown and Krumholz (2002) created a training programme for fostering undergraduate and graduate students' information literacy, which was based on the ALA information literacy standards. Although the literacy level of undergraduate students improved after completing the information literacy training, some problems, such as the sole focus on available sources without expanding the search process beyond local or online resources, persisted. For high school students, Lorenzen (2001) found in a qualitative study based on interviews that the majority of students use the web and libraries. Most of the students interviewed used both and some relied exclusively on the web, although none relied on libraries as a single source of information. O'Brien and Symons (2005) reached the same conclusions in a quantitative analysis of undergraduate students. Klucevsek and Brungard (2016) reported that university students mainly rely on Google and Google scholar for their queries. A mere 10% of students also use other databases such as Science Direct SciFinder or Scopus. Because of this limited information-seeking behaviour, students have difficulty finding adequate primary literature and therefore prefer secondary sources for their work.

Little is known about research sources and strategies in the subject of biology. Julien and Barker (2009) examined information literacy skills in biology students at high school level, using in-class task assignments and semi-structured interviews. Fifty-nine percent of the information sources students used in this study were web-based, with Google being the most commonly used search engine and sometimes referred to synonymously with the web. At university level, Fuselier et al. (2017) reported positive effects of contextualised science information literacy lessons in a general education biology lab as opposed to subject-specific lectures only. They found a decreased use of basic Google searches and textbooks, and an increased use of online databases.

As information and communication technology developed, and the problem shifted towards information overload, the handling of contradictory or fake information, and the critical handling of sources, information became the centre of interest in information literacy research. With background knowledge being a crucial prerequisite for critical evaluation skills, it comes as no surprise that younger children tend to believe that everything written online is true, especially when the same information appears in different sources (Anderman et al., 2012;

Hirsch 1999, Van Deursen and Van Diepen 2013). Older students usually have broader domain-specific knowledge and are aware of evaluation criteria. The International Computer and Information Literacy study reveals that, although nearly all 8th grade students use ICT in order to obtain information, only about 23% have the ability to critically evaluate information (Fraillon et al. 2014). Walraven et al. (2009) analysed the amount of evaluation and the evaluation criteria used during information searches among 9th grade secondary students and found that evaluation was rarely used. Information was critically evaluated less often than search results and sources were almost never questioned. If an evaluation of search results took place at all, students most frequently used the title and/or summary as a decision-making criterion. Usability, including the amount of information provided by a source, was the most frequently cited evaluation criterion, whereas the criteria of verifiability or reliability were neglected. The evaluation of sources was purely based on technical criteria such as retrieval speed. Paul et al. (2017) found that 9th grade students possess the necessary knowledge for evaluating sources, but whether or not they apply that knowledge to evaluating sources depends on their motivation, contextual variables and the salience of the source information at hand. Julien and Barker (2009) reported higher levels of competence in later high school years, with 42% of students comparing multiple resources for consistency and 48% looking for bibliographies. Even at university level, students rely on structural elements of sources, including citations, URLs or methodologies, when deciding whether an article is scientific (Bromme et al. 2015; O'Brian and Symons 2007).

Even when appropriate written information sources are obtained, it is necessary to extract the relevant information from them. Science reading is a challenging task, as science texts often describe and explain complex phenomena, use a typical, expository text structure, and learning about science topics outside the classroom requires reading multiple texts (Britt et al., 2014; Fang 2006). Biology textbooks are frequently used as written information sources in science teaching (Smith et al. 2010). Unfortunately, research reveals that students have difficulty understanding these texts (Starauschek 2003), especially when they contain large amounts of technical terminology as is typical in science (Kahveci 2010). Carnine and Carnine (2004) report that up to 80% of middle school students are unable to understand science textbooks, either because their reading skills are generally inadequate or they have trouble constructing scientific meaning. According to the 2015 PISA results, an average of about 20% of students from OECD countries at the end of lower secondary school possess poor general reading skills and are therefore classified as a 'high-risk group' for reading (OECD 2016). Reading science texts is not simply a process of decoding written symbols in order to construct meaning. It also involves the reader's prior knowledge, beliefs, prior experiences and understanding of socio-cultural contexts (Spence 1995; Yore and Shymansky 1991). For the subject of biology, Ozuru et al. (2009) demonstrated a positive correlation between prior knowledge and understanding of biological texts in their assessment of general reading skills. Cromley et al. (2010) also reported a positive effect of prior knowledge on the comprehension of biological texts, but found that inference had an even greater effect on the comprehension of such texts.

Teachers' Information Literacy

Information literate teachers are a prerequisite for effective information literacy training in class. Research on information literacy among teachers focuses on one of three aspects: (1) teachers' knowledge about information literacy (Moore 2000), (2) their own ability to employ literacy skills

(Williams and Coles 2007) and (3) the attitude of teachers towards information literacy (Merchant and Hepworth 2002; Moseley and Higgins 1999; Wen and Shih 2008). With regard to the first aspect, Duke and Ward (2009) state in a meta-analysis of 39 articles that pre-service and in-service teachers are often insufficiently prepared for teaching information literacy and research skills to their students. Smith (2013) reports a limited understanding of the term ‘information literacy’ among high school teachers, in addition to teachers feeling ill-prepared despite having received relevant training. In the same study, teachers also tended to overestimate the information literacy skills of their students. When asked to rate their confidence in their own ability to monitor students’ progress, 65% of teachers in the International Computer and Information Literacy Study were positive that they could master such a task (Fraillon et al. 2014). Probert (2009) examined the knowledge and application of information literacy among secondary school teachers. In their study, about 60% of teachers showed limited understanding of the information literacy concept, and about 20 to 40% (dependent on the school cluster) considered information literacy to be synonymous with information and communication technology (ICT). A number of teachers—regardless of age and years in service—did not explicitly teach information literacy skills, while others did not follow an information-processing model, or said they did but failed to name the stages of the model used. There are numerous methods for teaching information literacy, most of which are aimed at librarians (Grassian and Kaplowitz 2001; Elmborg 2006; Loertscher and Woolls 2002; Wang 2007). And yet, little is known about how teachers actually implement information literacy teaching in class, and there is no information about how accurately teachers diagnose their students’ information literacy skills.

Questions

With reference to the information literacy rubric on based on the Austrian science standards, the present study addresses the following questions:

- What sources do 8th grade, 10th grade and 12th grade students use for obtaining biological information? Are there any differences in source selection between students of different grades?
- What competence levels from the Austrian science standards (see Table 3) do 8th grade, 10th grade and 12th grade students possess when it comes to obtaining and extracting information?
- Are the information literacy skills of 12th grade students more developed than those of 8th grade and 10th grade students?

According to the literature (for example, Julien and Barker 2009; Lorenzen 2001; O’Brian and Symons 2007), it is expected that students show a preference for internet sources. Accordingly, students’ evaluation competences are expected to increase with years in school.

As far as teachers are concerned, the study focuses on answering the following questions:

- How effective are teachers’ diagnostic competences in rating their students’ information literacy?
- How much time do teachers spend on information literacy activities in class?
- Does information literacy depend on the time spent on literacy activities in class?

Given that little information is available about teachers’ competences when it comes to diagnosing information literacy, and research on the diagnostic skills of teachers for other

aspects varies in accuracy, no reasoned guess can be made here. According to Lorenzen (2001), there is reason to assume that teachers do not spend much time on information literacy activities, and if they do, the lack of explicitly taught information skills may lead to average results, even when more time is spent on these tasks.

Sample

The sample comprises 391 Austrian 8th, 10th and 12th grade biology students from different school types (middle schools, schools providing general higher education, upper schools) and their 46 biology teachers. One hundred sixty-six (42.5%) of these students attend 8th grade, 124 (31.7%) attend 10th grade and 101 (25.9%) attend 12th grade (final year). Half of the biology teachers teach biology only, 26.1% teach a second subject and 21.7% teach three or more subjects (especially in middle schools). The most common additional subjects thought by biology teachers are English (12%), chemistry (10.9%) and mathematics (8.7%). Geography, physics and German are also included in the list. The teachers' average teaching experience is 23.83 years, with five teachers having less than five years of experience, three teachers from five to ten years, 12 teachers from 11 to 20 years, six teachers from 21 to 30 years and 16 teachers having more than 30 years of teaching experience.

Methods

The students had to complete a questionnaire consisting of two parts: finding sources for information and extracting information from school textbook texts. For the first part, they had to imagine they were to give a presentation about a biological topic in class and the teacher did not provide them with any information. Subsequently, they were asked what sources of information they would use, where they would be able to find these sources and which quality criteria they would consider for choosing different sources. In the second part, they were given two texts on biological topics (animals, plants, ecological systems, the cardiovascular system, cells, nutrition, soil and rocks, the brain and sensory organs)—one similar to texts from junior class books and one similar to those from senior class books. The students then had to answer 'true or false' questions about these texts.

In the teachers' questionnaire, the teachers had to rate their students' average competences when it comes to selecting adequate information sources and giving criteria for evaluating them, as well as extracting biological information from simple texts (similar to texts from junior class school textbooks) and more complicated texts (similar to texts from senior class school textbooks). The teachers reviewed the students' questionnaires before answering these questions in order to permit them to provide an adequate rating. In addition to giving competence ratings, they were asked what percentage of their teaching time they devote to different information literacy activities.

IBM SPSS 22.0 was used in order to evaluate the data.

Results

Five different aspects of information literacy were examined: naming information sources, knowing where to obtain the named sources, listing quality criteria for information sources, extracting

information from simple biological texts (similar to those used in junior classes) and extracting information from more complicated biological texts (similar to those used in senior classes).

Overall, 87.9% of the students examined were able to name at least two different sources of adequate biological information for in-class presentations. 74.7% of 8th grade students were able to name at least two sources, while about 95% of 10th and 12th grade students named at least two different information sources. Since homogeneity of variance was not given, Kruskal-Wallis tests and Mann-Whitney tests were used to check for differences between grades. As far as naming information sources is concerned, there are significant differences between grades ($\chi^2 = 11, 84; p < .01$). These results are due to differences between 10th and 12th grade ($Z = -2, 34; p < .05$) and between 8th and 12th grade ($Z = -3, 43; p < .01$). On average, 8th grade students named 1.94 sources per person, 10th grade students named 2.27 sources and 12th grade students named 2.42 sources. Across all grades, online sources and specialised books were named most frequently. The older the students, the more unlikely it is that they ask people who are not engaged with the topic (see Table 4).

Beyond naming sources, 76.1% of students were also able to tell how to access these information sources. In 8th grade, this was only the case for 63.6% of students, whereas in 10th grade, 81.2% of students mastered this task, and in 12th grade, 89.5% answered correctly. The Kruskal-Wallis test revealed a significant difference between grades ($\chi^2 = 23, 92; p < .001$). The result can be explained by differences between 8th grade and 10th grade ($Z = -3, 16; p < .01$), and 8th grade and 12th grade ($Z = -4, 48; p < .001$). However, only 36.8% of students could name quality criteria for information sources (such as published by a renowned researcher or institution; review of articles; cross-checking of sources). In 8th grade, only 13.9% of students named adequate criteria. In 10th grade, 41.9% managed to complete this task, and in 12th grade, two thirds of students gave correct answers. The results from the Kruskal-Wallis test show differences between grades ($\chi^2 = 70, 84; p < .001$), resulting from differences between all grades (8th and 10th grade: $Z = -5, 16; p < .001$; 10th and 12th grade: $Z = -3, 54; p < .001$; 8th and 12th grade: $Z = -8, 42; p < .001$). A Friedman-test for paired samples was conducted to check for differences in difficulty between the three aspects of competence. The results show significant differences ($\chi^2 = 304, 25; p < .001$): naming sources appears to be easier than describing how to obtain information, which in turn is easier than naming criteria for evaluating information sources (see Table 5).

Table 4 Percentage of students who named the following sources of information for finding adequate information to give a presentation on biological topics

	8th grade	10th grade	12th grade
Internet	81.81	90.32	89.11
Specialised books	47.24	54.83	63.36
Textbooks in school	8.48	12.10	25.75
Exercise books	1.21	0.80	2.97
Encyclopaedias	7.89	4.03	4.95
Daily newspaper	2.42	2.42	1.98
People specialised on the topic	11.51	32.26	28.00
Teachers	6.67	8.87	4.95
Parents	10.30	3.23	1.98
Friends	7.27	3.23	1.98
TV documentaries	3.00	8.06	3.96
Master thesis	0.00	0.00	2.97
Others	0.00	3.26	0.00

Table 5 Percentage of students from different grades for each of the three aspects of the information search component of information literacy

	All students	8th grade	10th grade	12th grade
Naming information sources (level 1)	87.9	82.1	88.0	96.8
Describing how to obtain information sources (level 2)	76.1	63.6	81.2	89.5
Naming criteria for evaluating information sources (level 3)	36.8	13.9	41.9	66.3

Information extraction was divided into information extraction from simple texts (similar to those in junior class biology textbooks) and more complicated texts (similar to those in senior class biology textbooks). 80.1% of students were able to answer three ‘true or false’ items related to the simple texts correctly. In 8th grade, 70.5% of students were able to answer those items correctly, whereas 84.7% of 10th grade students and 90% of 12th grade students mastered this task (Table 6). The Kruskal-Wallis test revealed significant differences between grades ($\chi^2 = 17, 30; p < .001$). This result is due to differences between 8th and 10th grade ($Z = -2, 82; p < .01$) and 8th and 12th grade ($Z = -3, 70; p < .001$). Extracting information from the senior class text was only mastered by 47.1% of the students examined. In 8th grade, 31.3% of students answered the three text-related items correctly, while in 10th grade, 57.3% and in 12th grade, 60% of students were able to answer those items correctly. The results differed significantly between grades ($\chi^2 = 28, 33; p < .001$). The differences between 8th and 10th grade amounted to $Z = -4, 41; p < .001$ and the differences between 8th and 12th grade to $Z = -4, 58; p < .001$. Answering questions related to the junior class text was easier for the students than answering questions about the senior class text ($Z = -10, 64; p < .001$). Students who showed good results for junior class texts also did so for senior class texts ($r = .47; p < .01$).

To determine the diagnostic competence of teachers as far as information literacy is concerned, the similarity between teachers’ judgement and students’ performance was computed. The teachers’ judgement was assessed on a binary scale, stating that most of the students in their class either did or did not possess the required competence aspect. Students’ performance was specified by the percentage of students in class who possessed the required competence aspect and could therefore also be converted into binary judgements. SPSS offers various options for computing similarities between binary variables. For the present study, the simple matching measure was used, which is computed by dividing the matching value pairs by the total of all pairs. Therefore, a value of 1 means that all values were rated correctly, while a value of 0 means that no value was rated correctly. A value of 0.5 defines the probability of guessing (Table 7).

Barely at guessing level, the poor judgement-performance matching for naming criteria for information sources is striking. In more specific terms, 12 of the 46 ratings were false

Table 6 Percentage of students from different grades for each of the two aspects of the information extraction component of information literacy

	All students	8th grade	10th grade	12th grade
Extracting information from easy biological texts (similar to texts in junior class textbooks)	80.1	70.5	84.7	90.0
Extracting information from more complicated biological texts (similar to texts in senior class textbooks)	47.1	31.2	57.3	60.0

Table 7 Values of the simple matching measure for computing similarities between teachers' judgement and students' performance for different aspects of information literacy (information search 1 = naming information sources; information search 2 = describing how to obtain information sources; information search 3 = naming criteria for evaluating information sources; information extraction 1 = extracting information from junior class biology textbooks; information extraction 2 = extracting information from senior class biology textbooks)

		Students' performance				
		Information search 1	Information search 2	Information search 3	Information extraction 1	Information extraction 2
Teachers' judgement	Information search 1	0.78				
	Information search 2		0.82			
	Information search 3			0.53		
	Information extraction 1				0.88	
	Information extraction 2					0.67

positives, meaning that teachers thought most of their students could master their task although this was not the case. Only four ratings were false negatives, where teachers believed their students would fail, when in fact, they did not. The opposite was the case for information extraction from senior class biology textbooks, where many 8th grade teachers rated their students' competences negatively but misdiagnosed their performance.

Teachers report that they spend different amounts of time teaching information literacy skills, varying from zero to more than half of their teaching time. However, increased time spent on information literacy activities does not correlate with better results ($r = -0,09$).

Discussion

Information literacy plays a fundamental role in scientific literacy, given that the selection, critical evaluation and use of information is crucial for functioning successfully in the twenty-first century (Case and Given 2016; Emery et al. 2015). School science aims to provide students—even those without intentions to attend university—with adequate knowledge and skills for becoming actively participating citizens as far as science topics are concerned (OECD 2015). As most scientific data is derived from empirical sources, the critical handling of information is of particular importance (Bromme and Goldman 2014; Majetic and Pellegrino 2014). Therefore, skills related to obtaining and evaluating information must be an essential component of the science curriculum. This seems even more important when considering the poor scientific literacy competences of middle and high school students. Although students at that age are well equipped with ICT and are used to dealing with new technologies in their everyday lives, they do not possess suitable competences for dealing with information (Fraillon et al. 2014). In fact, secondary students often rely on online sources and do not evaluate sources and content appropriately, even if they can name criteria for evaluating information sources (Anderman et al. 2012; Julien and Barker 2009, Paul et al. 2017, Van

Deursen and Van Diepen 2013). But even at university level, many students fail to locate and critically evaluate information (Bromme et al. 2015; O'Brian and Symons, 2007).

The present study deals with information literacy skills of students in lower and upper secondary education in Austria and examines not only their preferences for different sources, but also their critical evaluation skills of information and sources. What is more, a key focus of this study is on the understanding of information from science texts, as the extraction of knowledge from different sources also constitutes an important aspect of information literacy. As far as the preference for online sources is concerned, the findings of the present study are consistent with the literature, where secondary students as well as students at university level mainly rely on the internet for their information queries (Klucevsek and Brungard 2016; Lorenzen 2001). At all three class levels examined in our study, between 80 and 95% of students were able to name at least two different sources of information, while online sources were named most often. In keeping with the findings of Julien and Barker (2009), many students named Google or Wikipedia synonymously with the Internet. The younger the students, the more they tend to rely on the knowledge of other people like their biology teachers or parents. Younger students also more frequently reported the use of school books when looking for information. Regarding the critical handling of sources, in this older students are more concerned with evaluating sources compared to their younger counterparts. This is unsurprising, given that previous studies have demonstrated that students at the end of junior school rarely evaluate the sources and results of their search processes, and tend to believe that everything written on the Internet is true, especially if the information can be found on various websites (Anderman et al. 2012; Hirsch 1999, Van Deursen and Van Diepen 2013, Walraven et al. 2009). In the present study, authorship and the cross-checking of information of several sources were most frequently named. However, even in 12th grade, only about 65% of students were able to name adequate evaluation criteria. But as prior studies have proved, the ability to name evaluation criteria does not necessarily mean that students use these criteria for evaluating information (Paul et al. 2017). Although nearly all students have access to online information via personal devices (OECD 2015), students at the end of secondary education were not concerned with the reliability and validity of data. Students of that age tend to believe that everything written on the internet is true (Hill and Hannafin 1999). In the present study, when students refer to the expert status of the author as a criterion for their evaluation, they do not explain their understanding of what being an expert means. When students execute information cross checks, they solely rely on different Internet sources without checking for validity with other sources such as books or their teachers.

Reading science texts is a complicated process involving the reader's prior knowledge, beliefs and a fundamental understanding of the socio-cultural context (Cromley et al. 2010; Spence 1995; Yore and Shymansky 1991). In addition, scientific texts are difficult to understand as they describe complex phenomena and use a special language which students are not used to read (Britt et al. 2014; Fang 2006). Therefore, we may assume that students not only have difficulty obtaining information, but that they often also lack the ability to understand relevant information in texts. This problem even occurs with school book texts, which are characterised by reduced complexity and are specifically written for this sample. In the present study, 30% of 8th graders were unable to retrieve information from age-adequate school textbooks, compared to about 40% of 10th and 12th graders, who were unable to understand age-adequate school textbooks. Overall, these results are unsurprising, as the reading skills of Austrian students are generally poor (OECD 2016) and school textbooks are often judged as being too difficult to understand for students (Starauschek 2003).

In order to teach information literacy, teachers not only have to be information literate themselves, but they also have to possess knowledge about models of information-processing and adequate teaching strategies. As many teachers lack both, it is unsurprising that information literacy is not taught at all in many classes (Probert 2009; Smith 2013). Little is known about the diagnostic skills of teachers for information literacy, but it has to be assumed that their competences for diagnosing their students' information literacy skills are limited and that they tend to overestimate their students' abilities (Probert 2009; Smith 2013). The present study revealed grave deficiencies in its examination of teachers' diagnostic skills. Especially for the criterion of evaluating sources, teachers rated their students' skills too positively. Overall, teachers tended to overestimate their students' skills in the information search process.

Conclusion

Summing up the findings of the present study, deficiencies in terms of information literacy skills exist among both students and teachers. Although accessibility of information and use of sources have changed dramatically in recent years, students are insufficiently prepared for handling the flood of information they are constantly exposed to through portable ICT devices like smartphones. In Austria, most students are able to identify information, but show little concern for the reliability and validity of the information they locate. In times of fake news manipulating people's judgement, contradictory or outdated information and sources circulating on the web and expert opinions on any topic being authored by unverified sources, this information handling behaviour bears considerable risks. Schools have a duty to empower their students to become critically thinking citizens. To achieve this goal, teachers across all subjects must actively promote strategies for dealing with information in their domain in addition to imparting domain-specific knowledge. As far as science teaching is concerned, it is vital to teach basic scientific knowledge and knowledge about the nature of science, as both are a precondition for the critical evaluation of sources. In addition, science teaching must impart skills for dealing with information efficiently and critically in order to enable students to make appropriate decisions in science-related contexts.

Despite ever-increasing demands in the area of information literacy, many teachers do not adequately respond to changing information handling needs. They overestimate their students' ability to critically handle information. A growing awareness of the necessity to explicitly teach information skills is needed in order to deploy information-processing models and teaching strategies which actively promote information literacy. Well-trained teachers who feel competent to teach information skills are the key when it comes to improving students' information literacy. In order to support biology teachers, further research on adequate teaching strategies for fostering information literacy in biology classes at junior and high school level is urgently needed.

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