# Information Literacy of Doctoral Students in Engineering

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Abstract

After a reform of the doctoral study programme at authors' faculty, an introductory course on scientific research methods became mandatory. It includes the topic of information literacy (IL) and covers its five main elements according to ACRL 2000 standards. A librarian/researcher runs the practical part. After this course has been running for seven years we were interested in its impacts: (1) what are students' subjective impressions about the course and (2) if and how such a systematic education on IL topics objectively impacts their publishing and citations.

The paper first presents the results of the questionnaire among 120 PhD students (the response was 67.5%, i.e. 81 of them) conducted immediately after the completion of the IL course. Four indicators were measured to address question 1: relevance, usefulness, complexity, and compliance with expectations. Question 2 was approached by examining students' citation practices in their own PhD theses and their publishing results. The hypothesis was that the IL course increased students' competence. It was tested using quantitative parameters, such as the number of references in PhD theses and the number of scientific publications written during the study and shortly after it. Students' age and duration of study were also analysed, separately for reformed program students who attended the IL course, and separately for pre-Bologna reform students who did not take this course. We found that although pre-reform students on average cited a few more references than their post-reform colleagues there were smaller differences among post-reform than among pre-reform students. Also the median/typical post-reform students cited more. With post- reform students, the number of references was not correlated with age while in pre-reform it was. Post-reform students graduated faster and published more own quality work than their counterparts. Some of the better statistics from post-reform students over pre-reform students can be attributed to the information literacy course. This is also confirmed in the subjective answers in the questionnaire.

Key words:
PhD students, information literacy, engineering sciences, Slovenia.

## 1  Introduction

Gathering scholarly information in the 21th century is increasingly limited to using web-based search engines such as Google or Bing rather than using bibliographic databases, reference books, or librarians (Wertz et al., 2013). Students often use the criterion of quantity rather than quality when searching and gathering information online: they accept the first five ranked information sources, regardless of their quality or the quality of lower ranked information (Holliday and Li, 2004). This could be improved by making information literacy (IL) courses part of the regular scholarly education process.

## 1.1 Information literacy in standards

In the Information Literacy Competency Standards for Higher Education the information literacy is defined as a conglomerate of self-directed learning and reflective judgment of the ability to plan and pursue information searches and skills for evaluating the accuracy of information and its sources (ACRL). IL means not only analysing, synthesizing, evaluating, using, and disseminating the information, it is understood as the cognitive-affective network that enables individuals to recognize their need for information and understand it, evaluate it and use it by producing a new knowledge (Pinto, M. 2010), and used to resolve problems by making decisions (Elmborg, 2006). The main purpose of IL is to create habits for lifelong learning (Pinto et al., 2013). Nevertheless, as Volkwein et al. (2006) found in their research conducted among engineering graduates, life-long learning is one of the lowest ranked skills, despite the high emphasis on it in the contemporary society. There are many lifelong learning attributes, such as to identify, retrieve and organize information; understand and remember new information; demonstrate critical thinking skills; etc. In their publications, Riley et al. (2009) and Shuman et al. (2005) emphasized that information skills are critical components of lifelong learning.

Students' perception of their own levels of information competence are important for their self-confidence and motivation for high-quality work. This is a subjective aspect of students' information competence, which influences their research and academic work not only during their studies but also in their professional career. It is also important to realize that access, management, and use of information at the PhD degree level is more effective and research-purpose-oriented if students gain the basic knowledge of IL previously, i.e. in high school and undergraduate programs.

According to the standard ACRL (2000) there are 5 phases that incorporate IL:

**1. Information gathering.** Bursic and Atman (1997) found that senior students gathered more information, they are of higher variety than those used by younger students. For engineers in business companies Atman et al. (2007) realised that they spent significantly more time gathering information than students. There are many reasons for this, as engineers have no knowledge of IL and they also lack access to information sources like databases and journals. It is evident that business companies do not want to pay for subscriptions and they do not employ a librarian as a specialist for information seeking and gathering. Companies that have a librarian are very rare (26% of 109 companies analysed), and even when there are librarians employed they are not highly educated. Only 20% of companies had a librarian with the title of Masters of the Library Science or its equivalent. Many persons who work as librarians have their primary job obligations outside of the library and have little or no training in librarianship. Many of them work part-time. This means that more self-sufficiency among engineers is required, as they cannot expect to receive good research assistance from a librarian, often they cannot expect any assistance at information retrieval from the professional staff. Often senior engineers with many experiences teach their younger colleagues about information sources retrieval (Napp, 2004).

**2. Information evaluation.** Kim and Sin (2007) realized that trustworthiness, accessibility, and ease of use are high-ranked criteria of information gathering by students. Wertz et al. (2013) are convinced that content and context-based criteria for evaluation are source credibility, reputation, and bias, but they realised that the primary criterion, as identified by undergraduate students, is convenience.

**3. Information application.** The results of some studies into engineering research habits showed that senior-level students use more information and pieces of evidence to support their recommendations (Cole and McKenna, 2010; Younker and McKenna, 2009).

**4. Information documentation.** With open science and open publishing new types of bibliographical units are presented, such as blogs, short communications, open discussions, and authors often have difficulties how to cite these publications.

Yu et al. (2006) are convinced that all students of engineering have difficulties with IL. They mostly use online sources and there is a high misalignment between in-text citation and bibliography. This is generally consistent with the conviction of Denick et al. (2010) based on their study. On the other hand, Fanelli (2010) find out that, in the field of engineering, between 75 and 95% of analysed papers reported a support for testing their hypotheses, according to geoscience and environmental & ecological sciences, where among 65 and 85% analysed papers corresponded to that argument. The poor knowledge about information documentation among engineering students was shown also by the study of Wertz et al. (2013), where three quarters of the students made at least one big documentation mistake so that the information sources were not rediscovered.

**5. Information dissemination**. Through the knowledge gained in IL students are classified to disseminated their own publications to colleagues via the existing paths such as ResearchGate, LinkedIn and similar network systems. The scientists of the 21th century should be qualified to self-archive on their own web page and deposit their work in institutional repositories as well. (Wertz et al., 2013)

## 1.2   Local experiences

With the introduction of the Bologna reform, according to the Bologna Declaration (1999), in the Slovenian university education programmes and at Faculty of Civil and Geodetic Engineering at the University of Ljubljana, Slovenia, (UL FGG), a new doctoral study program was launched in the academic year 2009/2010. Among others chievements of the Bologna reform the IL became a mandatory common course for PhD students. It introduces scientific research of the built environment as lectures (30 hours). Lectures are given by a senior professor experienced in education and scientific work. The practical part (15 hours) is run by a librarian with a PhD degree. In line with the curriculum, the students of engineering sciences are educated about the 5 main elements of IL. They also get professional instruction on how to use internationally recognized multidisciplinary bibliographic databases such as Web of Science (WoS) and Scopus, engineering-subject oriented databases such as Iconda, Georeff, Geobase, Compendex, and Inspec, as well as Slovenian bibliographical database systems like COBISS, SICRIS, DIKUL, dLib, which are greatly useful for PhD students. The students are required to prepare a scientific article according to the IMRAD scheme, where special attention is given to the list of references, particularly on the quality of citations. For this purpose, instructions for UL FGG students and other users were published, first in 2005 (Koler-Povh, 2005).Regarding the instructions, only the information sources, which were used and implemented in the theses can be included in the these's chapter References.

In line with open-access trends in scientific communication, the PhD students obtain knowledge about open access journals, especially those from technical sciences, experiences by browsing in digital repositories for publications and data, particularly the UL FGG Repository – DRUGG (http://drugg.fgg.uni-lj.si/), which was built in 2011 and where all the theses since 2010 are archived, many also from previous years, (Koler-Povh et al., 2014) and is a part of the Repository of the University of Ljubljana – RUL https://repozitorij.uni-lj.si/info/index.php/slo/, since 2015.

In the spirit of collaboration between engineering faculties and faculties for library and information sciences (Bowles-Terry et al., 2010; MacAlpine, 2009) in the new PhD curriculum at UL FGG this collaboration is carried out via a senior lector with many experiences in teaching and research work, who is also a member of many editorial boards of worldwide recognized professional and scientific journals, as the leader of the curriculum, and a collaboration of the highly skilled and experienced librarian who works as the head of UL FGG library. This collaboration testifies to the importance of involving an information specialist in the education process.

UL FGG's curriculum goals are the following:

- raising students awareness about their need for information gathering,
- developing the competencies for self-confident and responsible scientific research work,
- helping students develop appropriate strategies to access and evaluate information,
- teaching students to appropriately use and dissemination of sources with reference to copyright.

Starting from the fact that the level of prior information literacy knowledge by students of engineering sciences is low, in our study we wanted to identify the PhD students competencies in relation to knowledge, skills, and attitudes toward the information immediately after the course. For this reason we analysed the opinion of seven generations of post-Bologna reform PhD students, by using questionnaire analyses.

To recognize the influence of IL on their research qualification we analysed references, used and cited in PhD theses and publications made during the study and shortly after it (during a 5 year period). We did this separately for post-Bologna reform students who attended the IL course and separately for pre-Bologna reform students who did not. We also analysed the influence of duration of PhD study and student's age.

## 2 Related studies and publications

There are several papers about IL in undergraduate study programmes but only a few related to PhD level studies. Also, the instructions for IL are mostly tailored to the needs of undergraduate students, while information needs of PhD students are different than those by undergraduate students. The students will attend an IL course only if they realise that it will help them to address their needs (Fleming-May and Yuro, 2009; Hoffmann et al., 2008; Macauley and Green, 2009; O'Malley and Delwiche, 2012). These instructions are also not appropriate for researchers as their needs are quite different too. A big difference is that researchers usually first identify a concrete problem and then search for a solution to be used in practice (industry).

### 2.1 Users' behaviour – specific needs of PhD students and practitioners

PhD students are required to exhibit much more competent information behaviours (Macauley and Green, 2009), i.e. acknowledging when the info is needed, acquiring and assessing the info, converting it into knowledge, making an original contribution to professional knowledge and practice, and being prepared for lifelong learning.

The ACRL 2000 standards defining and articulating the need for information recognise that "existing information can be combined with original thought, experimentation, and/or analysis to produce new information" (ACRL, 2000). The question-defining process of a PhD student includes 4 phases (ACRL, 2000):

1. The student confers with instructors and participates in class discussions, peer workgroups, and electronic discussions to identify a research topic or other information need.
2. Develops a thesis statement and formulates questions based on the information need.
3. Explores general information sources to increase familiarity with the topic.
4. Defines or modifies the information need to achieve a manageable focus.

PhD students should keep up-to-date with the use of specialized literature, they should recognize their need for information and use skills for searching, locating, organizing, evaluating, and presenting information, first of all because of writing their PhD theses, which makes them more specialised in IL than established researchers (Wertz et al., 2013). Macauley and Green (2009) researched PhD students' engagement with information and IL learning and identified the specialized needs of PhD students. They include a need for individualized learning processes about scholarly communication, the literature review process, deployment of information and the specialized knowledge relating to the appropriated and unique topics and to the doctoral process with an emphasis on the original contribution to professional knowledge and practice, which should results in lifelong learning. The experiences of American and Australian PhD students with IL knowledge were collected via interviews, and the need of specialized information demands of advanced learning was examined. PhD students are required to exhibit relatively competent information behaviours.

As Pinto et al. (2013) found out, PhD students in Spain and Latin America are highly confident in their IL knowledge and information competence. The PhD students are expected to be highly competent in IL and their PhD theses are of the highest quality.

## 2.2   PhD students from practice

The PhD students from practice (industry) as committed practitioners due to their experiences and habits seek to solve problems of significance, drawing on their professional career and concerns. Their academic engagement remains motivated by the commitment. On the other hand, as practitioner researchers they value efficiency, timeliness and convenience (Macauley and Green, 2009). Roberts et al. (2014) have investigated perspectives and practices of PhD researchers and faculty members in relation to research and practice in librarianship and information management. They conducted a survey among PhD students of the University of Sheffield's Information School (iSchool), in which they explored their motivation for undertaking the research, their views about the impact of research, and the role of social media in its dissemination. By analysing journal articles published by iSchool faculty, with an emphasis on their subject matter and references (among others), they demonstrated the collaboration with practitioners in conducting

and communicating research. They identified five criteria important for connecting research with practice. Their realisation is a starting point for assessing the relationship of research studies and practice in the field.

These five criteria, according to Roberts et al. (2014), are:

1. Motivation from practice to conduct the research for describing a framework of research problem.
2. Practical or policy implications from the research.
3. Specific strategies for transferring research into practice.
4. Specific and useful outputs for practitioners from the research.
5. Implications for research arising from the work, including suggestions for future research or development of a theoretical framework.

Through these five types of statements, explicitly relating the research to practice, many recommendations for conducting and communicating academic research in LIS are intended to strengthen the relationship between research and practice. They are useful in other scientific fields as well. Among the recommendations, the collaboration through the interest of all involved parts is emphasized, the engagement of students, the practitioners, and also the alumni for strengthening of motivation, relevance, and filling of education gaps identified in the literature (Roberts et al., 2014).

## 2.3   The librarian's role in Information literacy of PhD students

The librarian's role is to introduce the PhD students to IL knowledge and use of IL skills to help them understand »information as a process of discovery and construction meaning rather than a process of accumulating« (Macauley and Green, 2009). Exner (2014), a librarian herself, describes exactly the role of the librarian in helping PhD students in their studies. She highlighted the main important fact in the communication between a PhD student and a librarian, the possibilities of a librarian to understanding original researchers. She emphasises the need that the librarian should examine the existing literature on researchers, information needs. She distinguished between researchers who are information synthesizers – they combine existing (publishing) knowledge to answer their research question, and the original researchers', who find the answers in an empirical way, through investigations and analyses or case studies. Their structure of information needs differs. Exner (2014) is convinced that the researchers want to understand how the tools incorporate into their research plan, so it is important to include plenty of discussion of how information planning and tools interact. She emphasized the need of original research and collection of data on information needs and behaviour of PhD students as researchers in IL processes. Our research is probably the first one of this kind.

Hence the literature review has a central place in PhD theses (Boote and Beile, 2005), the collaboration between PhD student and the librarian is very important. Fleming-May and Yuro (2009) highlighted the difficulties of this communication because many academic librarians do not understand the PhD thesis process and the needs of PhD students, who are, on the other hand, embarrassed how and what to ask the librarian (Tunon and Ramirez, 2010). The life-long learning of librarians is in this context even more appreciated. Also, Robertson (2003) emphasized the role of a librarian in relation to IL of PhD students and the importance of including the librarian as an information specialist into the IL curriculum. Especially in the digital age of libraries, when the information providers enable the users the information without visiting the library, which is strongly connected with a fact that the librarian can make base their work on a subject outside the library, too. The role of an academic librarian is to support, enrich, and provide services in

person and on-line. Involved in the PhD curriculum, the academic librarian is aware of a PhD student' needs and it is in both of their interests to design and deliver services and programs that are useful, especially in the PhD student's time constraints (Robertson, 2003). The role of an academic librarian is to support, enrich and provide services. As Steinerova (2008) emphasized, users need support in discovering, decision-making, and participation.

## 2.4   Local studies of user needs

In Slovenia, there are some studies about planning and incorporating the innovative use of information-communication technologies (ICT) into teaching. The emphasis on enhancing student competences for his/her own professional development, where the ICT competences had been recognised as important in the process of the formation of teachers' professionalism, which is based on autonomy, inquiry, creativity, and innovation, was published by Istenic Starcic (2010). The students' competences were analysed in 2010 for students of geodesy at UL FGG (Istenic Starcic and Turk, 2010). Their preparedness for learning IL was recognised, trying to overcome some shortcomings in their ICT knowledge. In the newest study Istenic Starcic et al. (2015) consider that computer supported collaborative learning is provided in the physical presence of learners manipulating the same tabletop device. Also, Kosmatin-Fras and Grigillo (2016) reported about testing new methods in educating the students enrolled in the Master Programme of Geodesy and Geoinformation at UL FGG to reach higher motivation. The role of connections with practice was emphasized as well. The students were satisfied using the new methods of teaching as the methods of reaching knowledge, particularly practical knowledge.

Looking into the future, Land (2011) sees the role of IL for researchers and PhD students as a threshold concept, which "… can be seen as a crossing into a new conceptual space where things formerly not within view are perceived … It represents a transformed way of thinking and practicing, of reasoning and explanation, without which the practitioner finds it difficult to progress". Such a threshold concept offers adaptable guiding principles for attaining IL and critical thinking skills (Hofer et al., 2012).

## 3   Study of impacts of PhD level IL course

Starting from the fact (argued in the previous Section) that the level of prior IL knowledge of the PhD students of engineering sciences is low we wanted to learn about the PhD students' impressions about the acquired knowledge, skills, and attitudes towards information literacy. We did this by a questionnaire immediately after the end of each course. Then we were looking for the objective influence of IL competencies by using the citation analysis of references in their PhD theses. We are also measuring other factors, such as duration of PhD study, age of the candidates, and the number of scientific publications in a 5-year period before the ending of the PhD studies.

When delivering the IL course we realized that older generations of engineers have difficulties in information gathering and documentation, since they do not know how to access and use databases and that they do not know the standards for documentation. As Macauley and Green (2009) reported, PhD students from practice (industry) as committed practitioners are special as they are affected by experiences and habits, so in their study they seek knowledge for problems of significance, drawn from their professional career and concerns. Their academic engagement remains motivated by the commitment. On the other hand, as practitioner researchers they value efficiency, timeliness, and convenience. The librarians should

recognize all these characteristics and involve them in the information systems for their individualized and problem-oriented learning for converting the information into knowledge, so that successful PhD students became successful researchers prepared for lifelong learning.

The young generations of engineers, especially those with theses after 2005, when the Instructions for UL FGG's Theses' Writing and Documentation of Sources (Koler-Povh, 2005) were introduced, and who had received the IL course with an emphasis of the COBISS information system in their high schools (mandatory in the national high school curriculum) do not have this sort of difficulties. The young PhD students who come directly after finishing their undergraduate study programs have a lot of theoretical knowledge and they choose professional problems as challenges for their knowledge and study. Both groups of PhD students need individualized instructions from postgraduate learners and librarians as well. Including the academic librarian with experiences in this process at UL FGG was an important and helpful decision.

## 3.1   The survey

To gain insight into students' attitudes towards the knowledge gained in the IL course in relation to their engineering background, a questionnaire was conducted immediately after the completion of the IL course (for 7 generations, from 2009 until 2015). Four indicators were defined for this evaluation: Relevance, Usefulness, Complexity and Compliance with Expectations. Our research question was: Did the PhD students recognize the IL course as useful for their research activity?

From 2009 until 2015, 120 enrolled students in 7 generations attended the PhD including the IL course at UL FGG. Among them 81 PhD students took part in the mentioned survey; its purpose was to find out the students' perceptions of their own information competence – self-perception of their knowledge, skills and attitudes regarding information competence. The results of this analysis are presented in Figure 1.
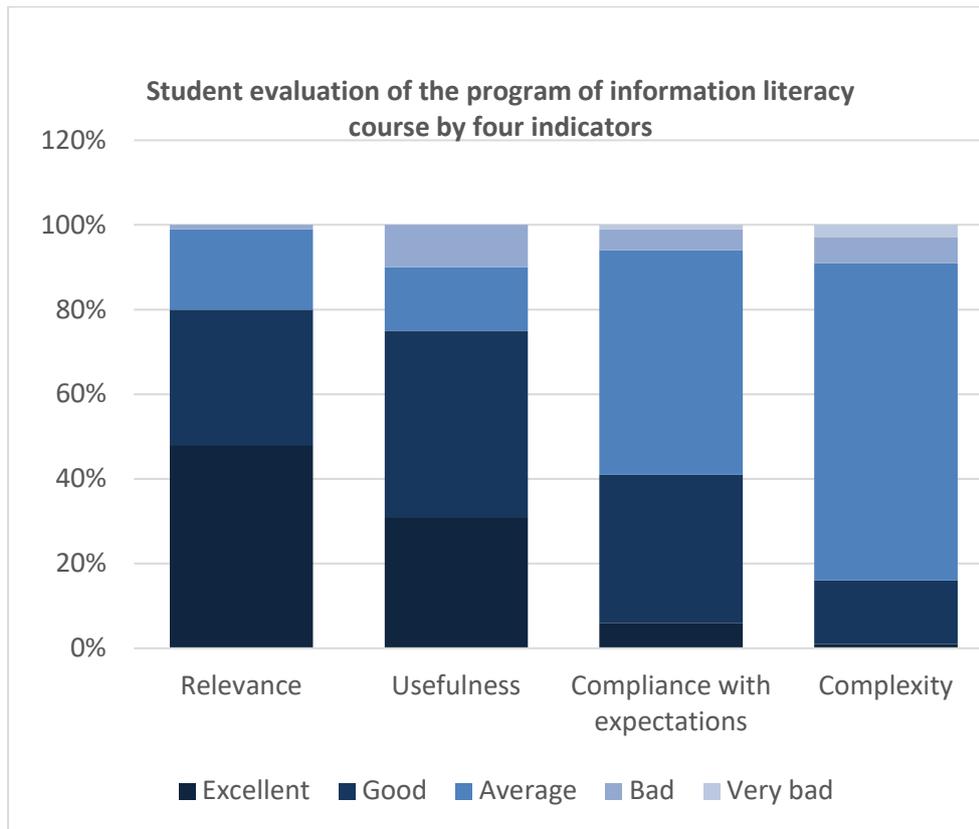
*Figure 1: Student evaluation of the information literacy course in terms of Relevance and Usefulness*

We learned that on the question "How do you assess the relevance of IL course subjects?", 19% of the students answered that they felt the course was relevant, 32% considered it very relevant and 48% of them considered it extremely relevant.

On the question "How useful was the IL course for your future work as researcher" 15% of the PhD students recognized the IL course as useful, 44% very useful and 31% extremely useful.

On the question "How did the course comply with your expectations", 53% answer it did, 35% that it did very much so and 6% that it exceeded the expectations.

On the question "How do you assess the complexity of IL course subjects?" 75% of PhD students felt it as appropriate, 15% as difficult and 1% as very difficult.

In short, engineering PhD students generally found the course very relevant and useful for their future work as researchers, it complied with their expectations and it was not too hard.

## 3.2   Analysis of the PhD theses

The generally positive subjective impressions of the students about the course were then verified by examining measurable outputs of the PhD students and examining various factors of influence. The number

of citations in their PhD theses was used as a proxy for the success or failure of the IL course. We assumed that it is positive to take into account and refer to more works.

For 65 PhD students who ended their study in the period- 2013–2016 (September), we analysed their PhD theses regarding the number of references cited in theses. We divided the students into two groups – pre-Bologna reform students (N = 31) who did not attend the IL course and the group of post-Bologna reform PhD students (N = 34) that did have the IL course. The period for analysis is short because the Bologna PhD study was introduced at UL FGG no sooner than in October 2009.

UL FGG's institutional repository DRUGG was used as a data source. Our hypothesis was: The post-Bologna reform students use and cite more references in their PhD theses than the pre-Bologna reform students. This can be, in part, attributed to the IL course.
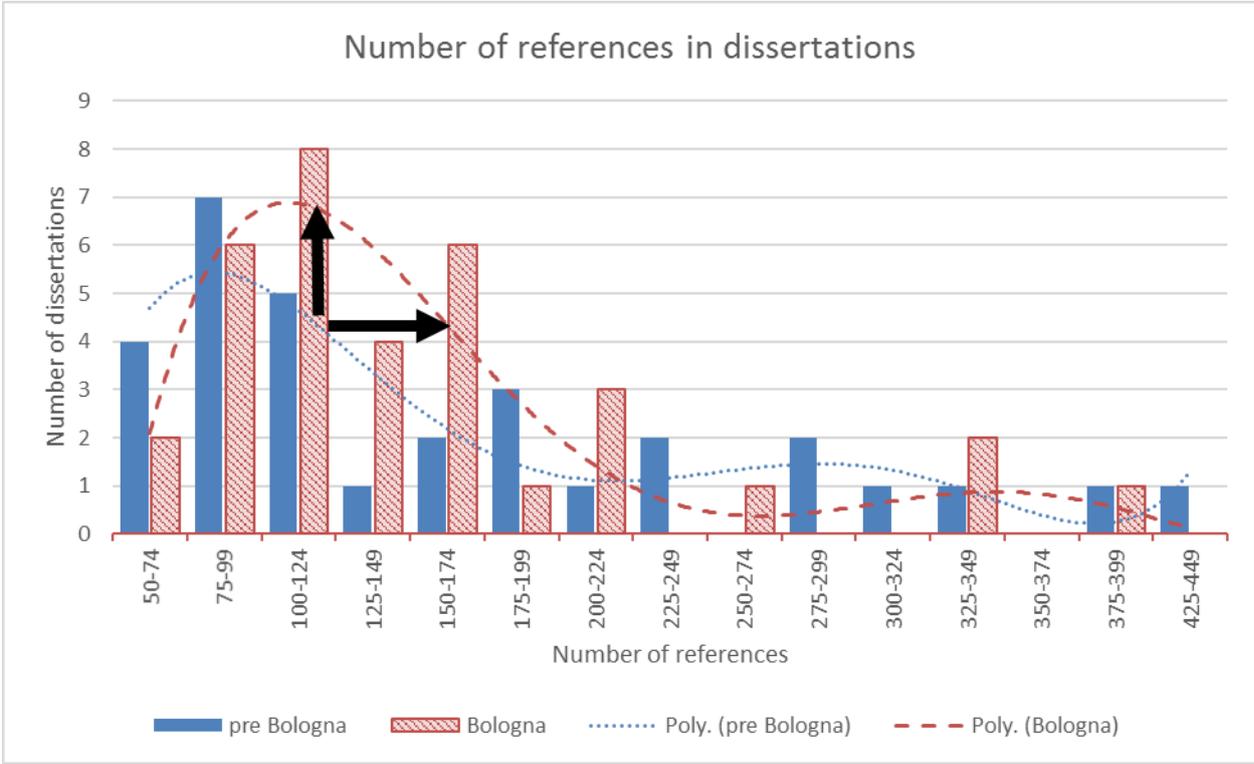


*Figure 2: Number of References in post-Bologna reform and pre-Bologna reform theses in the period from 2013 to September 2016*

The highest, lowest, and main values of the number of citations are presented in Table 1.

*Table 1: The highest, lowest and main values of the number of references*

|  | pre-Bologna PhD students | post-Bologna PhD students |
|---|---|---|
| **Min 2013-2016 Sept** | 50 | 59 |
| **Max 2013-2016 Sept** | 448 | 385 |

| | | |
|---|---|---|
| **Median 2013-2016 Sept** | 119 | 127.5 |

The statistical test of the null hypothesis presuming that the expected number of references is the same for theses from post-Bologna reform and pre-Bologna reform PhD students, was performed by a t-test. On average, post-Bologna reform PhD student use more sources (M = 127.5, SE = 10.5903) than pre-Bologna PhD students (M=119, SE=8.9143); however, this difference was not significant $t(63) = 0.73$, $p>0.05$.

Through the citation analysis of references in the PhD theses of 65 PhD students we recognized, that PhD students who attended the post-Bologna reform study curriculum and who gained the IL knowledge and skills cited just a few more references than their peers, which is evident through the number of references in the PhD theses (Figure 2 and Table 1).

As Figure 2 shows (and the median value confirms) the number of citations for the majority of PhD students is shifted by a full category (25 citations) to the left. A typical students that took the IL course cites more. Averages (and to some extent medians) are distorted because of the impact of students with extreme number of references.

To put that difference in perspective we continued to explore how the age of PhD students at the end of study and the duration of the PhD study affected the number of references in their PhD theses.

*Table 2: PhD students' age parameters*

| | pre-Bologna PhD students | | post-Bologna PhD students | |
|---|---|---|---|---|
| | Age | No. of references | Age | No. of references |
| **Min** | 29 | 50 | 26 | 59 |
| **Max** | 55 | 448 | 43 | 385 |
| **Median** | 34 | 119 | 30 | 127.5 |

As shown in Table 2 pre-Bologna reform students, at the end of their PhD study, are on average by 4 years older (M=34) than their peers at the post-Bologna reform study (M=30), but the difference in the age for the oldest students of the group is 12 years. 6 of the pre-Bologna reform students exceed the median value by more than 10 years, one of them even by 21 years. Between the post-Bologna reform students, the distribution is more homogeneous; only one student exceeded the median value by more than 10 years.
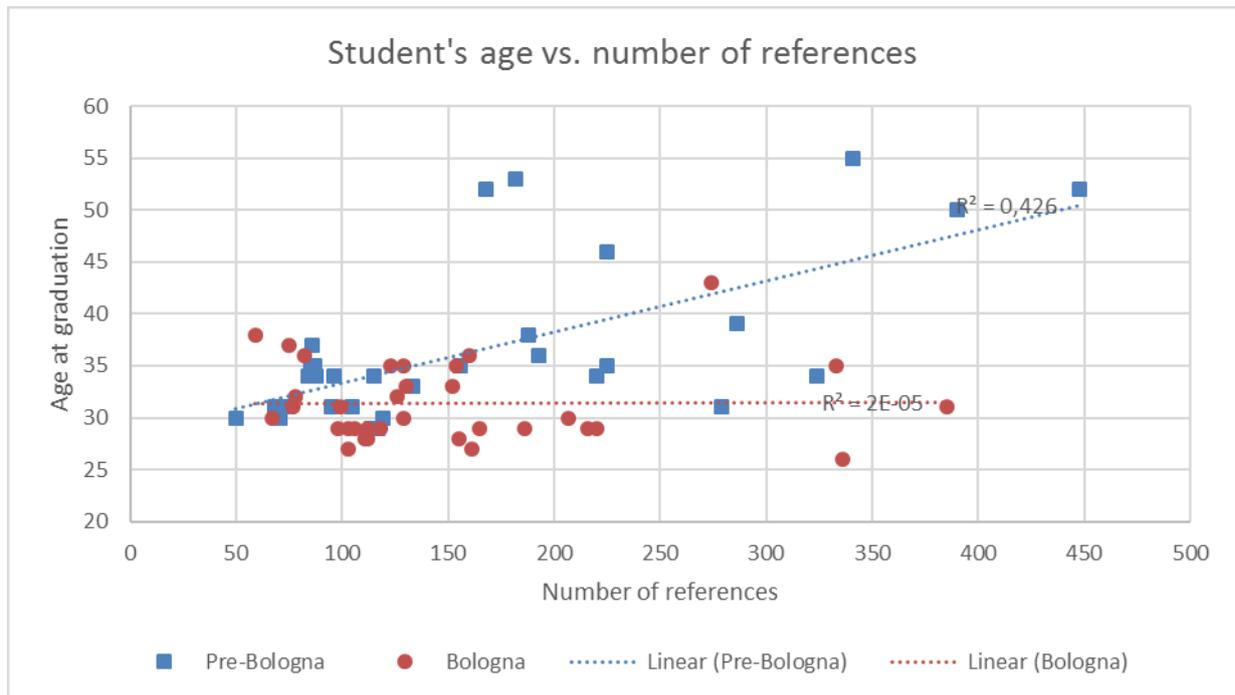
*Figure 3: Number of references per age of PhD students*

Regarding Figure 3, it is evident, that only for pre-Bologna reform PhD students the number of references is correlated with the age of the students. The statistical t-test confirms the affect of age of the PhD student for pre-Bologna reform students only, older pre-Bologna reform students cited more references in their PhD theses. Our results are the same as those by Bursic and Atman (1997), who found that senior students gathered more information than younger ones, but for pre-Bologna reform students only. It would appear that being exposed to systematic IL knowledge erased this difference and that IL knowledge acted as a substitute for experience.

Regarding the data on the duration of their study, the pre-Bologna reform students studied on average for 7 years and collected fewer references (MpBS=119) than post-Bologna reform students, who studied on average for 5 years and cited more references (MBS=127.5) in their PhD theses (Table 3). The difference is statistically significant by t(Stat) = 6.731737, α<0.05. In neither group, however, there seems to exist a link between duration of study and number of references.

The difference in number of references in PhD theses could be attributed to IL course that enabled more efficient literature studies.
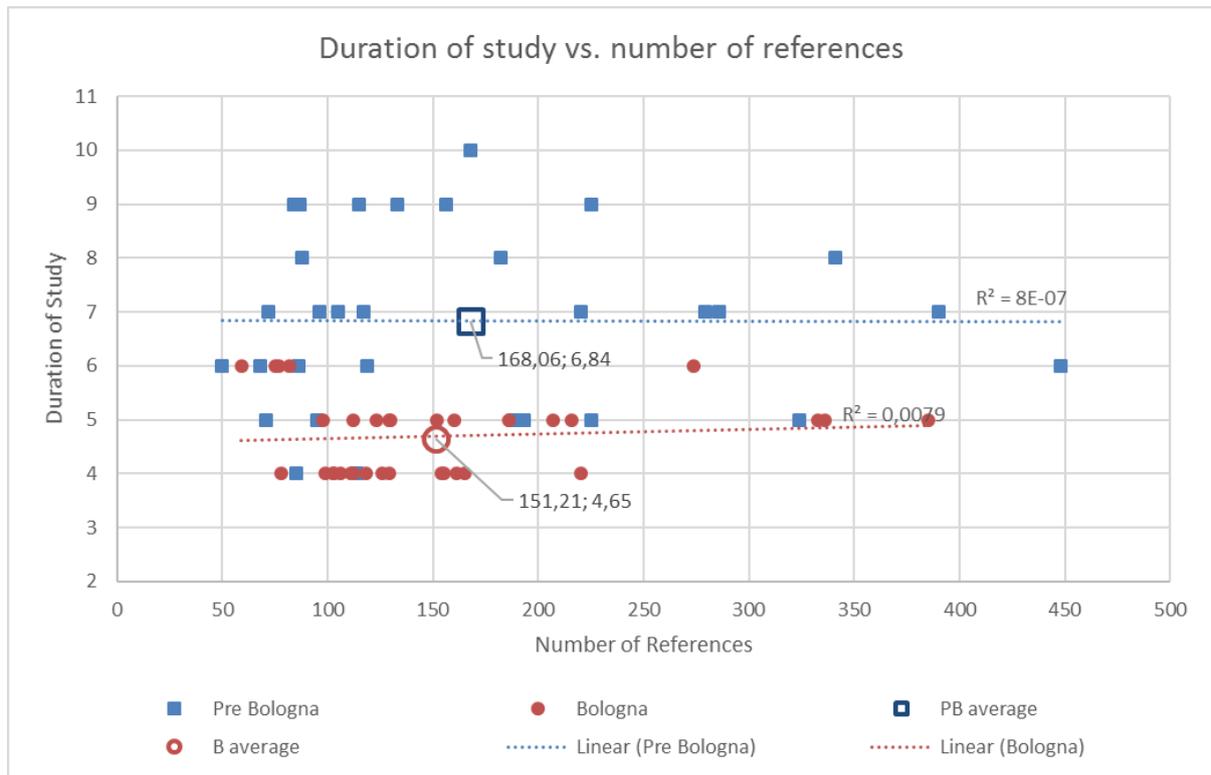
*Figure 4: Number of references compared to duration of PhD study*

*Table 3: The parameters for duration of PhD study*

|  | pre-Bologna PhD students | | post-Bologna PhD students | |
|---|---|---|---|---|
|  | Duration | No. of references | Duration | No. of references |
| **Min** | 4 | 50 | 3 | 59 |
| **Max** | 10 | 448 | 6 | 385 |
| **Median** | 7 | 119 | 5 | 127.5 |

We also analysed the number of scientific publications published by PhD students in the 5 year period. We were distinguishing between original journal papers and all other scientific publications (mostly conference papers). We observed a period of five years, i.e. between 2011–2015 for the students who finished their study in 2013, and 2012–2016 for the students who finished their study after 2013 until the end of September 2016. Regarding the age, we assumed that pre-Bologna reform students published some scientific publications before they finished their PhD studies, as many were active as scientists or experts in the industry for years. A factor contributing to more publications of post Bologna reform PhD students

could be that for them the publication of at least one JCR journal scientific paper before the end of the study is the condition of the regular PhD Bologna study program. The results are given in Figure 5.
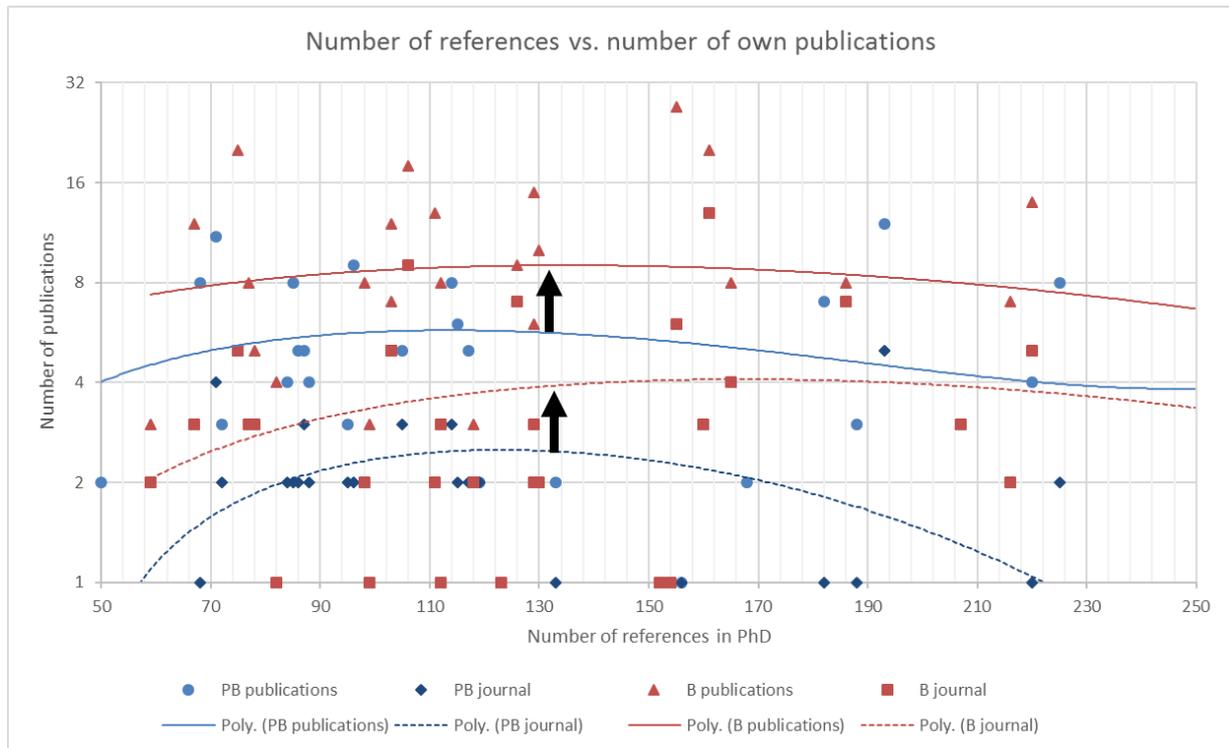


*Figure 5: Number of scientific publications published in a 5-year period (2011–2015 or 2012–2016). B=Bologna, PB=pre Bologna. Publications=all publications, Journal=original scientific journal papers.*

*Table 4: The parameters for the number of scientific publications of PhD students*

|  | pre-Bologna PhD students | | post-Bologna PhD students | |
|---|---|---|---|---|
|  | No. of scientific publications | Number of JCR journals scientific articles (among them) | No. of scientific publications | Number of JCR journals scientific articles (among them) |
| **Min** | 0 | 0 | 1 | 1 |
| **Max** | 33 | 16 | 27 | 13 |
| **Median** | 5 | 2 | 8 | 3 |

It is evident that post-Bologna reform students published on average more scientific publications in the 5-year period than the pre-Bologna reform students. By analysing the JCR journals scientific papers only, the post-Bologna reform students published on average 3, the pre-Bologna reform students 2; the difference is

not statistically significant for $\alpha = 5\%$, but with the risk of 8% we could confirm that post-Bologna reform students published more JCR journals scientific papers than pre-Bologna reform students (p value=0.801, when the t(63)= -1.4211). The correlation between number of JCR journals scientific publications and number of references in PhD theses exists for the average and below average number of references but is inversely correlated for theses with extremely high number of references (Figure 5.)

When considering all types of scientific publications, i.e. scientific articles, conference papers, and parts of scientific monographs, the post-Bologna reform PhD students published on average 8 and pre-Bologna reform students 5 publications. The difference is not statistically significant, t(63) = -1.0538, p>0.05.

# 4 Conclusions and discussion

The information literacy course which has been mandatory in the Bologna reformed PhD study program at UL FGG since 2009 gave the PhD students important knowledge and skills for their research and had a measurable positive impact on their scientific work.

Through the survey carried out among 7 generations of PhD students at UL FGG who attended the post-Bologna reform study programs that included an IL course, we realized that PhD students felt that the IL course was very useful. 81% found the course at least very relevant, 75% at least very useful, 41% that the course exceeded their expectations and 90% found it at least appropriate complex. We got the confirmation (subjective and objective) that their information knowledge competencies are higher than before attending the IL course. The students feel able to use appropriate skills for finding information and have acquired knowledge for collecting, evaluating, and using existing information in creating new knowledge and knowhow to disseminate it.

This is confirmed by the measured data from references used in their PhD theses, and their publications.

By analyzing the number of references in the PhD theses we realized that the median post-Bologna reform students cited more references (M pre-Bologna=119, M post-Bologna=127.5). Indeed they are on average four years younger than the pre-Bologna reform students. But age was a factor affecting the number of references only for pre-reform students but not for post-reform students. Also, since the Bologna-reformed study process requires at least one scientific publication (i.e. article in a JCR-ranked journal), the number of these articles is considerably higher for Bologna students. This points to the possibility that the recent changes are also a product of significant content-wide changes of Bologna reform, as described by Orosz (2014).

The lack of professional experiences does not affect the number of references cited. The difference is statistically not significant while t(63)=-0.7312, p>0.05, but this fact demonstrates, that the difference in number of references in PhD theses could be attributed to IL course.

The differences among students - between the highest and the lowest values of all the measured citation and publication parameters - are lower in the group of post-Bologna-reform PhD students. This can be attributed to the IL course: being exposed to common knowledge reduced the differences in pre-existing knowledge, the differences in experience and general IL literacy that comes with age (see Figure 3). The course could have some impact on the difference in the duration of PhD studies (4 vs. 6 years – see Table 3) although other factors probably played a role as well.

Both, results in the survey as well as measuring number of references and publications, show that through the IL course the PhD students gained useful knowledge and skills for their scientific work. All this is motivating the providers of the course to keep introducing new and relevant knowledge and skills into the syllabus.

Comparative studies in other disciplines should determine whether the impact of an IL course is particularly relevant for engineering PhD students where the focus of undergraduate and graduate education is concentrated in the natural sciences, technology and engineering problem solving, and the pre-existing formal information literacy knowledge is limited.

It is clear, however, that scientists-librarians have important and useful messages for future scientists in engineering and can disseminate knowledge that improves students' scientific work.

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