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# Does the Information Literacy of University Students Depend on their Scientific Literacy?

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**ABSTRACT**
Information literate students with a good understanding of science are regarded as an important pool of future successful professionals. The study explored correlations between the information literacy (IL) and scientific literacy (SL) of university students and analysed their achievements according to Bloom's cognitive categories of remembering, understanding and applying knowledge. A theoretical connection between IL standards and SL competencies was exposed. An information literacy test and a science literacy test, derived from the PISA 2006 science scale, were used for assessment. The results showed a significant moderate positive correlation between students' SL and IL. Students with a better understanding of science were more successful in all three cognitive levels of IL, and students with higher SL scores were better in the application of IL knowledge. A specialised credit-bearing IL course with active learning significantly improved the IL level of all students, most notably in applying IL knowledge, and thus reduced the initial IL disparities between students with low and high SL. The study brought the realisation that the IL of university students depends on their SL obtained in previous education; however, a well-designed university IL course contributes towards higher cognitive levels of IL for all students.
**Keywords:** Bloom's cognitive categories, higher education, information literacy, PISA, scientific literacy, university students

## INTRODUCTION

In the information era, information literate students with a good understanding of science represent a potential foundation for future successful professionals, such as engineers, medical doctors, innovators and scientists. In spite of this general recognition, very few authors have considered possible connections or correlations between students' information literacy (IL) and scientific literacy (SL). Until now, no systematic study has been performed to directly measure and analyse students' achievements in both IL and SL.


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**State of the literature**

- Information literacy (IL) is defined as an intellectual framework for understanding, finding, evaluating and using information.
- Scientific literacy is defined as knowledge and understanding of scientific concepts and processes.
- Until now, very few authors have considered possible connections between students' IL and SL. No systematic study has directly measured and analysed university students' achievements in both IL and SL.

**Contribution of this paper to the literature**

- There is a connection between SL and IL. The study provides a theoretical connection between IL standards and SL competencies, and demonstrates a significant moderate positive correlation between university students' IL and SL.
- Students who are good at understanding and applying scientific knowledge achieve a higher level of IL in all cognitive categories.
- A specialised credit-bearing IL course with active learning can reduce IL disparities between students with low and high SL, and significantly improve the IL of all students.

## Information Literacy (IL)

According to the Association of College and Research Libraries (ACRL), IL is defined as an intellectual framework for understanding, finding, evaluating and using information (ACRL, 2000). An information literate university student is able to: (1) determine the extent of the information needed; (2) access the needed information effectively and efficiently; (3) evaluate information and its sources critically and incorporate the selected information into one's knowledge base and value system; (4) use information effectively to accomplish a specific purpose; and (5) understand the economic, legal and social issues surrounding the use of information, and access and use information ethically and legally (ACRL, 2000, pp. 2-3). The concept was later adapted for scientific and technical disciplines (ACRL, 2006), with additional emphasis being placed on lifelong learning. IL has been recognised as essential for individuals to achieve personal, social, occupational and educational goals: to be effective in lifelong learning, to contribute in knowledge societies, to create competitive advantages of firms and nations within the global knowledge economy, and to participate in civic society, as active information seeking has become an essential part of democratic participation. Due to these reasons, IL has been endorsed by UNESCO as a basic human right (Catts & Lau, 2008).

However, some IL educators focus primarily on the use of information technology and on information search skills. This is not regarded as sufficient to achieve a deeper level of IL. Researchers are critical of such a tool-based approach, and argue that confining IL only to search skills denies learners the rich potential that may be gained from combining IL with the broader content and context of study fields, and with solving real problems (Bruce, 2008; Diekema, Holliday, & Leary, 2011). As a result, newer conceptions and interpretations of IL move beyond a purely skills-based approach, applying new strategies and methodologies of IL education with active learning methods (ACRL, 2016; Cheney, 2004; Dolničar, Podgornik, & Bartol, 2016; Lloyd, 2007; Munro, 2006). In this context, active learning can be regarded as any instructional method that engages students in meaningful learning activities and in thinking about what they are doing (Bonwell & Eison, 1991, p. 2; Prince, 2004, p. 1). In short, simply listening, watching and taking notes is not regarded as active learning. Students must do more; they must read, write, discuss issues, solve problems and undertake other active learning activities involving higher-order thinking tasks, such as analysis, synthesis and evaluation.

## IL, ICT and Digital Competence

IL skills are generally viewed as part of a larger constellation of generic adult skills and literacies. Information and communication technology (ICT) and digital skills have become an inseparable part of education, in order to prepare scientifically literate and digitally competent citizens (Xu & Chen, 2016). In the information society, IL develops in close conjunction with ICT; nonetheless, IL and ICT skills are recognised as separate and distinct, and should not be equated (Šorgo, Bartol, Dolničar, & Boh Podgornik, 2016). In contrast to IL, which focuses on information, ICT and digital literacies focus primarily on skills associated with various digital technologies. To clarify these similar terms: information technology skills "enable an individual to use computers, software applications, databases, and other technologies to achieve a wide variety of academic, work-related, and personal goals" (ACRL, 2000, p. 2), while the term ICT literacy refers to "[the use of] digital technology, communications tools, and/or networks to access, manage, integrate, evaluate and create information in order to function in a knowledge society" (International ICT Literacy Panel, 2002, p. 16).

Individuals need to possess a combination of cognitive and technical skills in order to apply digital technologies, web search engines and electronic databases, which are a primary source of information (Catts & Lau, 2008). In this context, a framework for developing and understanding digital competence in Europe (Ferrari, 2013) defined five areas as being essential for digital competence: information, communication, content-creation, safety and problem-solving. Within these areas, several sub-areas of digital competences can be recognised as similar and/or overlapping with the domain of IL; for instance, in the area of information (identifying, locating, retrieving, storing, organising and analysing digital information, judging its relevance and purpose), in the area of communication (communicating in digital environments, sharing resources through online tools), in content creation (creating and editing new content, integrating and re-elaborating previous knowledge, dealing with and applying intellectual property rights and licenses), and in the area of problem-solving (identifying digital needs and resources, making informed decisions, solving conceptual problems through digital means).

The International Computer and Information Literacy Study – ICILS 2013 (Fraillon, Schulz, & Ainley, 2013), which internationally assessed and compared students' computer and information literacy, revealed that, among other findings, many "digital natives" are not digitally competent, and that being born in the digital era is not a sufficient condition for being able to use ICT in a critical, creative and informative way. The study also revealed that, on average, girls outperformed boys in computer and information literacy, and that teachers who used ICT in their classes not only taught more effectively, but also developed a more transversal computer and information literacy in their students.

## IL and Scientific Literacy (SL)

Scientific literacy is usually defined as the knowledge and understanding of scientific concepts and processes. PISA 2006 (OECD, 2007, pp. 34-35) defines scientific literacy in terms of: (1) scientific knowledge – an ability to acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions; (2) understanding the characteristic features of science, being able to differentiate between evidence-based scientific explanations and personal opinions; (3) an awareness of how science and technologies influence the economy, the environment, culture and social organisation; and (4) a willingness to engage with science-related issues, and to apply a scientific approach to problem solving. An analysis and comparison of science competencies (PISA, 2006) and IL standards (ACRL, 2000) reveals several related features, as shown in **Table 1.** In addition, Berman (2013a) mapped ACRL based IL competencies with SL competencies, as defined by the US National Science Education Standards. Porter et al. (2010) pointed out that developing IL and SL requires similar cognitive skills and abilities. Similar IL-SL parallels were established between information-literate information seeking and scientific inquiry by Julien and Barker (2009). While both processes start with the eliciting of prior knowledge and end with the communication of results/findings, hypothesis generation in science was compared to planning a search strategy, evidence search to iterative search execution, and scientific argument construction to information evaluation.

While the impact of ICT use on students' achievement in science has been studied quite often (Luu & Freeman, 2011; Delen & Bulut, 2011; Kubiatko & Vlckova, 2010; Aypay, 2010; Petko, Cantieni, & Prasse, 2016), there has been little research of the relationship between IL and SL. A few studies (Todd, 1995; Bruehl, Pan, & Ferrer-Vinent, 2015; Jensen, Narske, & Ghinazzi, 2010) have focused on the inclusion of IL instruction in the science curriculum and its effects on academic performance. However, there have been no attempts to explore whether the IL level of students (prior to instruction) depends on their general SL level.

One example of discussing IL and SL measured by the PISA test was a conceptual framework paper by UNESCO that described a set of IL indicators for the transformation of information into knowledge and, among other things, discussed IL in relation to PISA assessment. The authors (Catts & Lau, 2008) noted that PISA assessments of scientific competencies included some elements related to IL, such as "Identifying scientific issues by identifying the keywords to search for scientific information", and "Interpreting scientific evidence, making and communicating decisions".

**Table 1.** Related features and parallels between scientific literacy (PISA 2006) and information literacy (ACRL, 2000)

| **Scientific literacy: science competencies specified in PISA 2006** (OECD, 2007, pp. 34-35) | **Information literacy: ACRL standards - performance indicators and outcomes** (ACRL, 2000) |
|---|---|
| **Identifying scientific issues**<br>• Recognising issues that are possible to investigate scientifically | **1:** The information literate student determines the nature and extent of the information needed. |
| • Identifying keywords to search for scientific information | **1-1.e** Identifies key concepts and terms that describe the information needed. |
| • Recognising the key features of a scientific investigation | **1-1.f** Recognises that existing information can be combined with original thought, experimentation, and/or analysis to produce new information. |
| **Explaining phenomena scientifically**<br>• Applying knowledge of science in a given situation | **4:** The information literate student, individually or as a member of a group, uses information effectively to accomplish a specific purpose. |
| • Describing or interpreting phenomena scientifically and predicting changes | **3:** The information literate student evaluates information and its sources critically and incorporates selected information into his or her knowledge base and value system. |
| • Identifying appropriate descriptions, explanations, and predictions | **3-1.** The information literate student summarises the main ideas to be extracted from the information gathered. |
| **Using scientific evidence**<br>• Interpreting scientific evidence and making and communicating conclusions | **4.3** The information literate student communicates the product or performance effectively to others.<br>**3.3.a.** Recognises interrelationships between concepts and combines them into potentially useful primary statements with supporting evidence.<br>**3.3.c.** Utilises computer and other technologies (e.g., spreadsheets, databases, multimedia, and audio or visual equipment) for studying the interaction of ideas and other phenomena. |
| • Identifying the assumptions, evidence and reasoning behind conclusions | **3.2.b.** Analyses the structure and logic of supporting arguments or methods.<br>**3.2.c.** Recognises prejudice, deception or manipulation. |
| • Reflecting on the societal implications of science and technological developments | **5:** The information literate student understands many of the economic, legal and social issues surrounding the use of information and accesses and uses information ethically and legally.<br>**3.2.d.** Recognises the cultural, physical or other context within which the information was created and understands the impact of context on interpreting the information. |

## SL and the PISA survey

According to Knobloch-Westerwick et al. (Knobloch-Westerwick, Johnson, Silver, & Westerwick, 2015), understanding the nature of science is a core component of SL. A scientifically literate person is expected to be able to critically evaluate science in media. In

PISA research (OECD, 2006; Nacionalni center PISA, 2008), SL is defined according to the concepts of natural science, natural processes and natural situations. An individual is required to deal with specific tasks, thereby identifying science concepts and applying them accordingly. Processes in the tasks are associated with description, explanation and prediction of phenomena, with an understanding of scientific inquiry, and with interpretation of scientific explanations and conclusions.

The PISA survey is a triennial international event that aims to evaluate education systems worldwide by testing the skills and knowledge of 15-year-old students in mathematics, science and reading.

Natural situations in PISA tasks address areas of science that are important in life, health, environmental protection and the development of technologies. The authentic problems in the PISA 2006 science scale range from simple tasks to more complex ones; first, existing information in the text is identified, then new information is acquired from various sources, after which the information is evaluated and finally integrated into the solution of the problem (OECD, 2006; Nacionalni center PISA, 2008).

The starting point for solving a PISA task is to understand the problem, and to define the known data and other necessary data. This is followed by the collection, verification and validation of the data and their connectivity. Mañá (Mañá, 2014) reviewed students' difficulties when using information to solve PISA tasks, and identified four main strategies to successfully solve the problem: to decide how to read the information, to comprehend the task, to decide when to search for information in order to solve the task, and to self-regulate the search process. Therefore, SL and IL seem to be connected and interrelated: students need to know how to obtain the key data and other information, as well as how to process them, reach solutions and interpret them correctly. In solving tasks, this approach is often not known to students or is difficult for them, particularly with regard to the understanding and use of information in the responses (Mañá, 2014).

## MOTIVATION AND RESEARCH QUESTIONS

Until now, very few authors have considered possible connections between students' IL and SL. Moreover, the results of PISA science tests have not been directly compared and interpreted in relation to the results of IL testing. Therefore, the main motivation of our research was to explore the potential connections between the SL and IL of university students. We wanted to explore whether the basic SL level, as measured by selected tasks from the PISA 2006 science scale (OECD, 2006; Nacionalni center PISA, 2008), correlates with the level of students' IL, as measured by an IL test (Boh Podgornik, Dolničar, Šorgo, & Bartol, 2015), designed according to the ACRL IL standards for higher education (ACRL, 2000). We also wanted to analyse potential differences in students' achievements according to the cognitive levels of a revised Bloom's taxonomy (Anderson & Krathwohl, 2000). In addition, we wanted to explore what students add to their IL foundation by completing a compulsory credit-evaluated IL study course, designed in line with the ACRL standards. We were also interested

**Table 2.** Sample questions from ILT with multiple choice answers, the assigned ACRL category and the cognitive level category

| Question and multiple choice answers in the ILT | ACRL category | Cognitive category |
|---|---|---|
| 14) I am exploring two-dimensional animations. Using the keyword 'animation', I have retrieved 33,314 documents in a database. Which of the queries listed below is the most appropriate for the next search?<br><br>a) animation AND (2D OR 2-dimension* OR two dimension* OR two-dimension*)<br>b) animation AND 2D AND 2-dimension* AND two dimension* AND two-dimension*<br>c) animation NOT (2D OR 2-dimension* OR two dimension* OR two-dimension*)<br>d) animation OR 2D OR 2-dimension* OR two dimension* OR two-dimension* | II -2d<br>Constructs a search strategy using appropriate commands for the information retrieval system selected (e.g., Boolean operators, truncation, and proximity for search engines; internal organisers such as indexes for books) | 3- Analysing, Evaluating |
| 29) What is the correct sequence of the elements in a research article?<br><br>a) Abstract-Bibliography-Introduction-Material and Methods-Results-Discussion-Conclusions<br>b) Abstract -Introduction-Material and Methods-Results-Discussion-Conclusions-Bibliography<br>c)Abstract-Conclusions-Introduction-Bibliography-Material and Methods-Results-Discussion<br>d) Introduction-Results-Discussion-Conclusions-Material and Methods-Bibliography-Abstract | IV-3a, 3c, 3d<br>a. Chooses the communication medium and format that best supports the purposes of the product or performance and the intended audience,<br>c. Incorporates principles of design and communication<br>d. Communicates clearly and with a style that supports the purposes of the intended audience | 1- Remembering |
| 36) I bought some old documents in a second-hand bookshop. Which of the documents can I scan and publish on my Webpage without authorisation?<br><br>a) an anonymous photo published in a women's magazine<br>b) an article from a daily newspaper<br>c) an original manuscript by William Shakespeare<br>d) a translation of a poem written by a living poet and published by a British publisher | V-1d<br>Demonstrates an understanding of intellectual property, copyright and fair use of copyrighted material | 2- Understanding, Applying |

in whether the basic level of SL influences and/or determines students' ability to achieve advancement in IL in higher education, and if so, on which cognitive levels such connections may exist according to Bloom's taxonomy.

In order to clarify these dilemmas, the following research questions were set as the guidelines of the study:

1. What is the level of students' IL and SL?

**Table 3.** Classification of 40 individual ILT items into subscales according to Bloom's cognitive categories

| ILT item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subscale B[1] | 1 | 2 | 1 | 2 | 3 | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 3 | 3 | 3 | 2 | 2 | 3 | 2 |
| ILT item | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| Subscale B[1] | 2 | 2 | 2 | 1 | 2 | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 1 | 1 | 3 | 3 | 3 | 1 | 1 |

[1] 1 –remembering, 2 – understanding, 3 – applying and higher levels of Bloom's taxonomy

2. Is there a connection between university students' achievements in SL and IL?
3. Is there a connection between students' cognitive levels in SL and IL?
4. Does a credit-bearing IL course with active learning improve students' IL on higher cognitive levels?
5. Does the level of SL influence the ability of students to progress in an IL study course?

## MATERIALS AND METHODS

### The Information Literacy Test (ILT) and cognitive levels

A validated information literacy test (ILT), consisting of 40 multiple choice questions with four possible answers, served as the main IL measuring instrument (Boh Podgornik et al., 2015). In terms of content, the ILT follows the recommendations of the ACRL standards for higher education, covers a diverse range of IL topics, and provides difficulty levels from lower to higher cognitive skills. Three sample questions from ILT are presented in **Table 2.**

For the purposes of the present study, the ILT questions (items) were categorised into subscales corresponding to Bloom's cognitive processes (Anderson & Krathwohl, 2000), as presented in **Table 3**. The categorisation was performed by a group of four specialists with experience in IL and education, with the final decisions being agreed by consensus.

From the total of 40 ILT items:

- 13 were categorised into subscale B1 – remembering (retrieving knowledge from memory);
- 16 into subscale B2 – understanding (extracting meaning from messages); and
- 11 into subscale B3 – combining applying (using a procedure in a situation) and higher levels, such as analysing (determining the relationship of parts in a whole), evaluating (critiquing, making judgements), and creating (putting parts together in a new way).

### The Science Literacy Test (SLT)

The science literacy test (SLT) consisted of 23 items covering 6 authentic problems, each containing multiple subtasks. The problems were selected from the set of PISA 2006 testing,

**Table 4.** SLT characteristics: correspondence of the 23 SLT items with the published OECD PISA test problems and subtasks (OECD, 2006); SLT item types; and the classification of SLT items into Bloom's cognitive categories

| SLT item | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OECD PISA 2006 problem | 1 | | | | | 6 | | | | 11 | | | | 13 | | 14 | | | 16 | | | | |
| OECD PISA 2006 subtask | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 1 | 2 | 3 | 1 | 2 | 3 | 4a | 4b |
| SLT Item type[1] | O | M | O | O | T | M | T | M | T | M | M | T | M | O | O | O | O | O | M | M | M | O | O |
| SLT Bloom category B[2] | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 2 | 3 | 2 | 3 | 3 |

[1] M – multiple choice, O – open-ended; T – 3 true/false type

[2] 1 –remembering, 2 – understanding, 3 – applying and higher levels of Bloom's taxonomy

published in the national language (Nacionalni center PISA, 2008), which was translated and adapted from the OECD (OECD, 2006). The topics included:

- the quality of drinking water – "Fit for Drinking" (SLT items 1–5),
- tobacco smoking and health – "Tobacco Smoking" (6–9),
- fermentation of dough – "Bread Dough" (10–13),
- air pollution – "Health Risk" (14–15),
- catalytic converter of car exhaust fumes – "Catalytic Converter" (16–18), and
- wind energy – "Wind Farms" (19–23).

Out of the 23 SLT items, 10 were of the open-ended type (marked O in **Table 4**), 9 were multiple choice with 1 correct answer (M), and the remaining 4 were a set of 3 true/false statements (T).

In order to enable a comparison of SLT and ILT cognitive levels in the present study, the SLT items were categorised into three cognitive domains. The categorisation was prepared by four specialists in science, pedagogy and psychology, with the final decisions being agreed by consensus. As a result, 4 PISA items formed the SLT subscale B1 (remembering), 11 items formed the subscale B2 (understanding), and 8 items formed the subscale B3 (applying and higher levels), as specified in **Table 4.**

## Test groups and settings

Students from three Slovenian higher education institutions, enrolled in study programmes of life sciences, health, technologies, education and informatics, participated in the study.

- The first test group (TG1, pre-test group) consisted of 493 students who took the ILT and the SLT before/without attending any IL specific classes.

- The second test group (TG2, a subset of TG1, the post-test group) comprised 205 students who completed a credit-bearing IL course of typically 3 credit points and 45 contact hours, typically one semester long. The course programme followed the ACRL standards for higher education (ACRL, 2000), which were adopted and translated into the national language (ZDBS, 2010). IL instruction included active learning approaches, such as exercises, project- and problem-based tasks, solving problems, writing and presenting reports, all of which were related to the students' fields of study. In addition to the ILT and the SLT taken prior to the IL course, the TG2 students took the ILT again as a post-test after completing the IL course. The intervention only included IL content, so the results of the ILT pre-test and post-test were interpreted in relation to the initial level of SL, as measured by the SLT at the beginning of the IL course.

Testing was conducted between January 2014 and November 2015, using either electronic versions of the ILT and the SLT available through the open access survey system 1ka (https://www.1ka.si//), or in a traditional printed form. In all cases, the students were supervised by teaching staff and followed the same experimental protocol.

## Statistical tools and analyses

The Statistical Package for the Social Sciences (SPSS®, IBM, version 22) was used for all statistical data analyses.

The analyses of the group TG1 (N = 493) were performed for:

- ILT and SLT separately: test reliability (Cronbach's alpha), average test score, item correctness, Pearson's correlation coefficient of item cognitive level with item correctness, Bloom subscale score distribution, and Pearson's correlation coefficient (or, in the case of non-normal distribution, eta correlation ratio) of subscale scores, with the test score;
- ILT and SLT together: ILT and SLT total score distributions, Pearson's correlation of SLT score with ILT score, Pearson's correlation (or eta) of total SLT and SLT subscale scores with total ILT score and ILT Bloom subscale scores, and independent samples t-test for comparison of two TG1 subgroups (with below and above average SLT) in the total ILT as well as ILT subscale scores.

The analyses of the group TG2 (N=205) included ILT pre- and post-test total score distributions, ILT pre- *vs.* post-test comparison for the total and the subscale scores (paired samples t-test), Pearson's correlation of total SLT score with total ILT pre- and post-test scores, and TG2 subgroup (based on SLT score) comparison in total ILT and subscale scores, for pre- and post-test.

## RESULTS

### ILT scores and cognitive levels

The reliability of the ILT was reconfirmed (pre-test data, N = 493, Cronbach's alpha 0.725). The total ILT score was calculated as the sum of points awarded for correct answers (correct answer = 1, incorrect answer = 0; max. score = 40). The average total ILT score in the TG1 group of students (before/without attending any IL specific study course) was 65.6%, which can be regarded as a sufficient general level of IL.

However, students were not equally successful in all ILT items and on all cognitive levels.

The mean scores achieved in individual cognitive categories 1–3 were 72.8%, 66.0% and 56.6%, respectively, signifying a decreasing ILT score with increasing cognitive difficulty levels.

**Figure 1** shows the individual ILT item correctness (% of correct answers) with item assignment to Bloom's cognitive categories. Three items (12, 20 and 36) were perceived as particularly difficult (correctness less than 30%); these questions required students to understand the meaning of raw unprocessed data – intellectual property rights – and to be able to apply legal and ethical principles. There was a small correlation observed between ILT item correctness and Bloom's categories (with lower correctness for items requiring applying knowledge and higher levels); however, it was not statistically significant (r = -0.288, N = 40, p = 0.071).

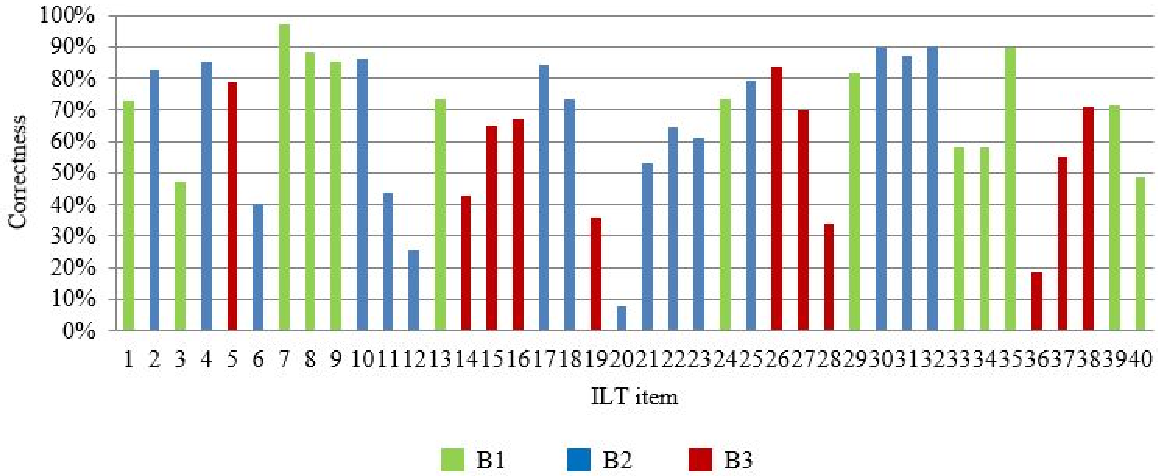


**Figure 1.** ILT item correctness (N = 493) with the assigned cognitive categories (B1 = remembering, B2 = understanding, and B3 = applying and higher levels)

The ILT score distributions for each cognitive category, presented in **Figure 2,** showed normal-like distributions, with lower scores in higher cognitive categories. The results indicated that the students were more successful in solving IL tasks requiring remembering than tasks requiring understanding and applying knowledge.

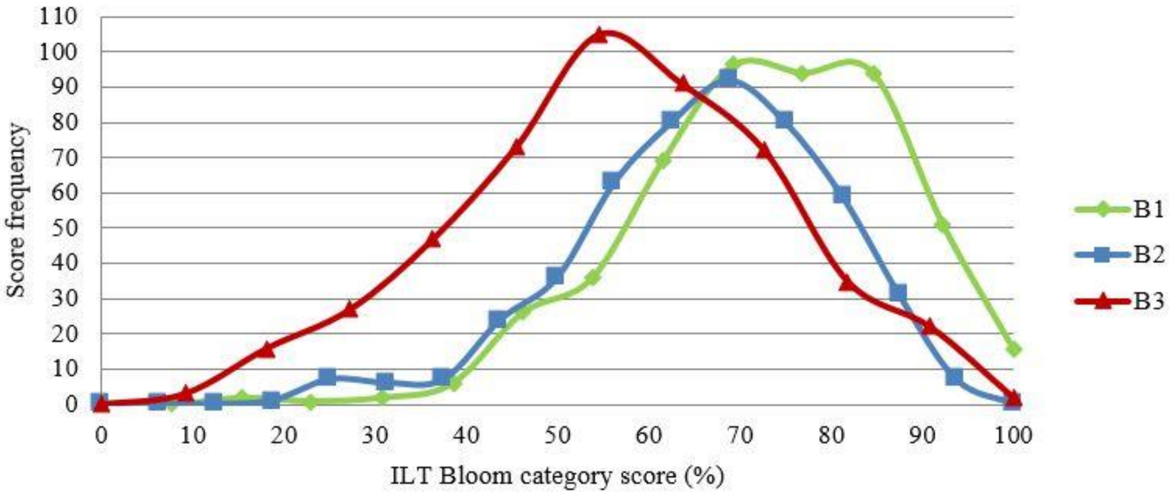


**Figure 2.** ILT score frequencies (N = 493) according to the cognitive categories (B1= remembering, B2 = understanding, B3 = applying and higher levels)

An analysis of Pearson correlations between the total ILT score and the ILT Bloom category scores showed that the correlations between individual Bloom category scores and the total ILT score were high, and the inter-subscale correlations were moderate (**Table 5**).

**Table 5.** Pearson correlations between total ILT score (N = 493) and ILT Bloom category scores (B1= remembering, B2 = understanding, B3 = applying and higher levels)

| | ILT | ILT B1 | ILT B2 | ILT B3 |
|---|---|---|---|---|
| ILT | 1.000 | 0.788 | 0.838 | 0.797 |
| ILT B1 | 0.788 | 1.000 | 0.490 | 0.453 |
| ILT B2 | 0.838 | 0.490 | 1.000 | 0.496 |
| ILT B3 | 0.797 | 0.453 | 0.496 | 1.000 |

## SLT scores and cognitive levels

The total SLT score was calculated as the sum of points awarded for correct answers (correct answer = 1, incorrect answer = 0; max. score = 23). The Cronbach's alpha of the test (N = 493) was 0.635. The average total SLT score was 67.1%, which can be regarded as a moderate level of SL.

The respective mean scores achieved in cognitive categories 1–3 were 89%, 68.5% and 54.1%, again indicating a decreasing SLT score with a cognitive category of increasing difficulty.

The analysis of individual SLT item correctness (% of correct answers) with item assignment to Bloom's cognitive categories (**Figure 3**) indicated that there was a significant high correlation between the cognitive categories and the item correctness (r = -0.598, N = 23, p = 0-003). The negative r value pointed to lower SLT scores in higher cognitive categories, indicating that the students were less successful in solving scientific problems requiring understanding and applying knowledge than in memory recall tasks.

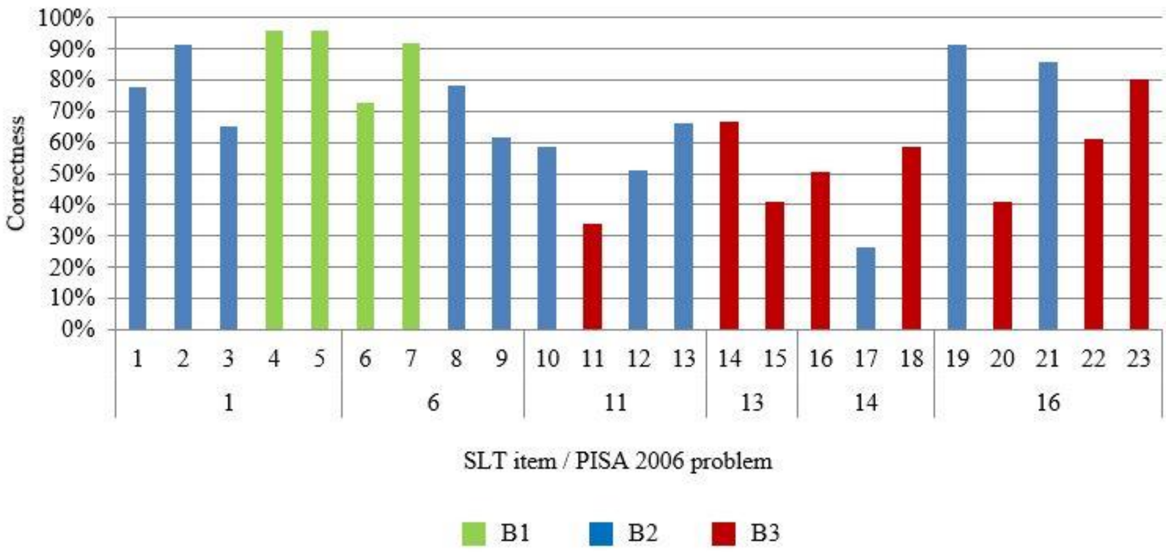


**Figure 3.** SLT item correctness (N = 493) with the assigned cognitive categories (B1= remembering, B2 = understanding, B3 = applying and higher levels)

The SLT score distributions for each cognitive category, presented in **Figure 4**, show normal-shaped distributions for the higher cognitive levels of applying knowledge (B3) and understanding (B2), but a non-normal curve for the category of remembering (B1). This indicates that the majority of students possessed a fairly good basic scientific knowledge and correctly answered most of the recall-type scientific questions, while in the categories of understanding and applying knowledge the scores were lower and the distribution better followed the normal Gaussian curve.

The calculated Pearson's (or eta) correlations between the total SLT score and the SLT cognitive category scores (**Table 6**) indicated a high correlation of the cognitive levels of understanding (B2) and applying (B3) with the total SLT score. Due to the non-normal distribution of the subscale score of remembering (B1), the eta correlation ratio was calculated instead of Pearson's correlation coefficient r, with similar results (magnitude of correlation). The subscale B1 (remembering) moderately correlated with the total SLT score. The inter-subscale correlations of B1 with higher cognitive levels were small, and the correlation between B2 and B3 was moderate. The results indicated that the students' ability to understand and apply scientific knowledge strongly correlated with higher SLT scores, while the impact of memory recall was only moderate. Remembering scientific facts was only weakly

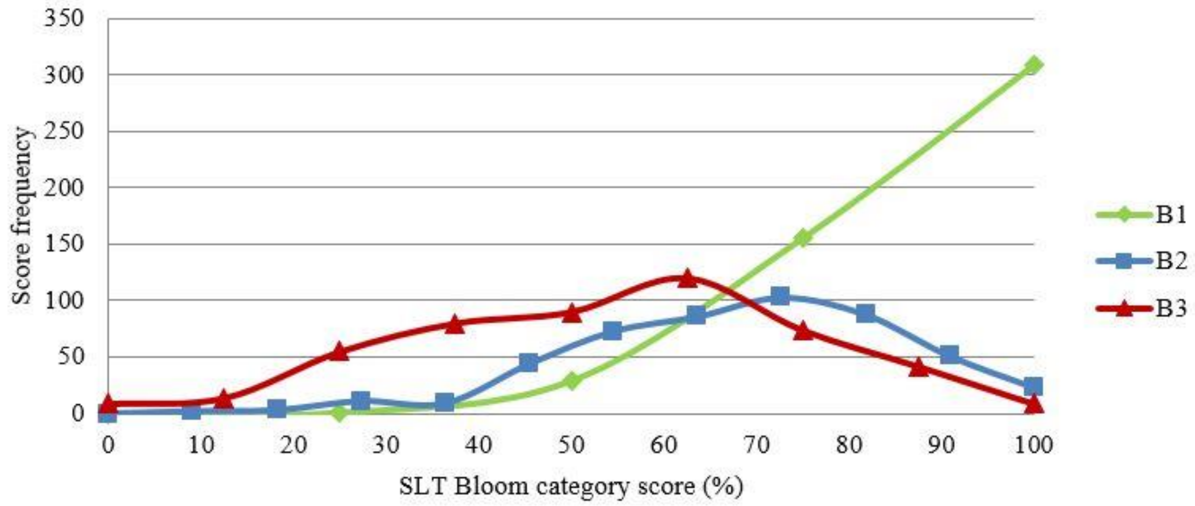


**Figure 4.** SLT score frequencies (N = 493) according to the cognitive categories (B1= remembering, B2 = understanding, B3 = applying and higher levels)

connected with the ability to understand and apply knowledge, while the abilities to understand and apply scientific knowledge correlated moderately.

**Table 6.** Pearson's (or eta) correlations between total SLT score and SLT Bloom category scores (N = 493)

| | SLT | SLT-B1 | SLT-B2 | SLT-B3 |
|---|---|---|---|---|
| SLT | 1.000 | (0.393) | 0.851 | 0.820 |
| SLT-B1 | (0.393) | 1.000 | (0.195) | (0.209) |
| SLT-B2 | 0.851 | (0.195) | 1.000 | 0.446 |
| SLT-B3 | 0.820 | (0.209) | 0.446 | 1.000 |

## SLT and ILT comparisons and correlations

A comparison of ILT and SLT score frequencies (TG1 N=493) showed similar, Gaussian-like distributions for both tests (**Figure 5**). A slight shift towards higher scores indicated that some knowledge and skills had been acquired in previous formal and informal education.

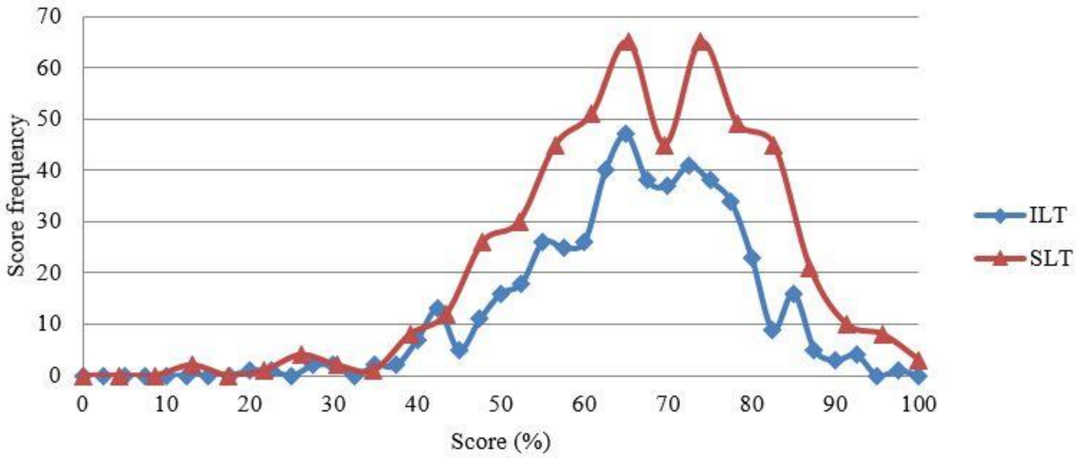


**Figure 5.** Comparison of ILT and SLT score frequencies in TG1 (N = 493)

The relationship between SLT and ILT scores was also illustrated as a scatterplot with regression line (**Figure 6**). Assuming a linear relationship, a significant moderate positive correlation was found between the two variables ($r = 0.487$, $N = 493$, $p < 0.001$), indicating that there was a connection between the students' achievements in the IL and SL tests, and that students with higher SL tended to also achieve better results in the IL test.

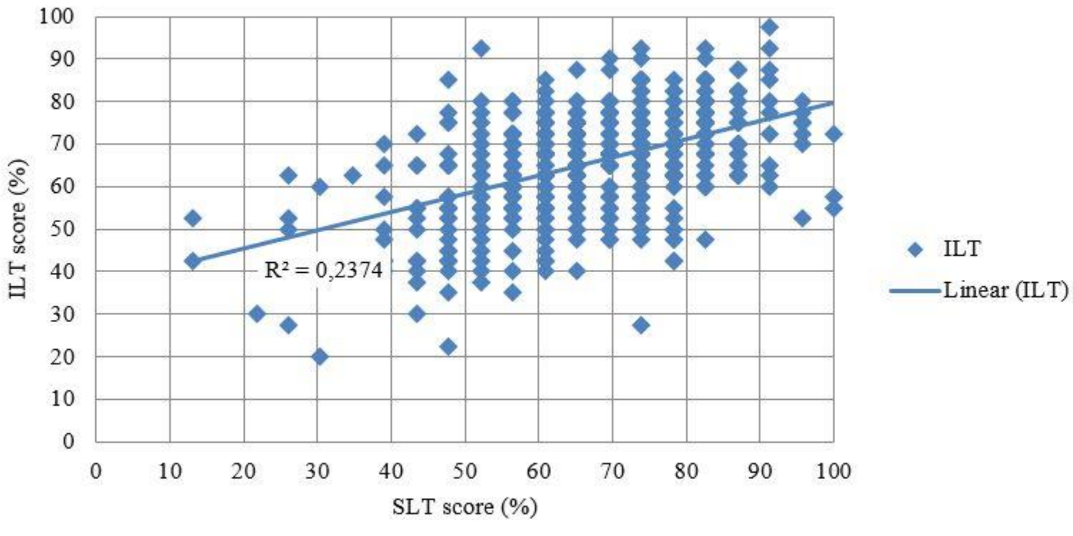


**Figure 6.** ILT score vs. SLT score with regression line (TG1, N = 493)

Calculations of Pearson's correlations (or eta) between ILT and SLT total scores and Bloom's cognitive category subscale scores (**Table 7**) revealed moderately high correlations of the SLT subscales corresponding to the higher two cognitive categories with the total ILT score. Like the total SLT score, the understanding SLT subscale (B2) correlated moderately with all three ILT subscales, while the correlations of the applying subscale (B3) with the same were low. The lowest correlations were observed in the remembering subscale (B1) of the SLT (correlations given as eta), with low correlations with the total ILT score and individual ILT subscales. These results suggest that the cognitive level of mere remembering of scientific facts had no impact on the level of IL, while the students who were able to better understand and apply scientific knowledge tended to also be better in the field of IL. Interestingly, the ability to understand natural science topics was moderately correlated with all three cognitive levels of IL; the students with a good understanding of scientific concepts tended to be better in all cognitive levels of IL: remembering, understanding and applying of IL topics.

**Table 7.** Pearson's (or eta) correlations between the ILT and the SLT, total and Bloom category scores (B1= remembering, B2 = understanding, B3 = applying and higher levels) (N = 493)

| | ILT | ILT-B1 | ILT-B2 | ILT-B3 |
|---|---|---|---|---|
| SLT | 0.487 | 0.374 | 0.413 | 0.393 |
| SLT-B1 | (0.177) | (0.153) | (0.155) | (0.129) |
| SLT-B2 | 0.488 | 0.382 | 0.423 | 0.376 |
| SLT-B3 | 0.337 | 0.244 | 0.280 | 0.293 |

In order to further explore the differences in students' IL levels based on their SL, we split the TG1 into two subgroups, according to the total SLT score: the first group, named TG1-b, with a below average SLT score (N1 = 247), and the second group, named TG1-a, with an above average SLT score (N2 = 246). The ILT scores of the two groups were compared using a t-test for independent samples. The results showed (**Table 8**) that the group with higher SLT scores performed significantly better in all aspects of ILT, with the biggest difference (12%) being achieved in knowledge application (B3). In other words, students who were successful in science were also better in IL topics, particularly in the ability to use their knowledge.

**Table 8.** T-test of independent samples for the comparison of two subgroups: TG1-b (students with a below average SLT score, N = 247) and TG1-a (students with an above average SLT score, N = 246) on the total ILT test score and ILT subscales (B1= remembering, B2 = understanding, B3 = applying and higher levels)

| ILT | Mean TG1-b | Mean TG2-a | Mean diff. | p | d |
|---|---|---|---|---|---|
| Total | 60.95 | 70.26 | 9.31 | 0.000 | 0.81 |
| B1 | 69.11 | 76.42 | 7.32 | 0.000 | 0.51 |
| B2 | 61.44 | 70.53 | 9.09 | 0.000 | 0.69 |
| B3 | 50.61 | 62.60 | 11.99 | 0.000 | 0.71 |

## Post-test results and effects of the IL study course

After initial testing with the ILT and the SLT, a group of 205 students (TG2) participated in a credit-bearing IL specialised course. The programme covered all topics of IL according to the ACRL standards of higher education, and aimed to promote different cognitive levels of

**Table 9.** ILT post-test improvement (paired samples t-test) in total ILT scores and in cognitive subscale (B1–B3) scores (TG2, N = 205)

| | | Confidence Interval | | | | | |
|---|---|---|---|---|---|---|---|
| **Scale** | **Mean Diff.** | **Lower Limit** | **Upper Limit** | **t** | **df** | **p (2-tailed)** | **d** |
| ILT total | 14.8 | 13.5 | 16.2 | 21.8 | 204 | 0.000 | 1.35 |
| ILT-B1 | 12.9 | 10.8 | 14.9 | 12.5 | 204 | 0.000 | 0.94 |
| ILT-B2 | 11.9 | 10.1 | 13.6 | 13.1 | 204 | 0.000 | 0.95 |
| ILT-B3 | 21.5 | 19.3 | 23.7 | 19.2 | 204 | 0.000 | 0.70 |

IL through a combination of lectures, practical exercises and active learning tasks. The content and practical examples were adapted to the specific fields of study.

After completing the programme, the students completed the ILT again as a post-test to evaluate the impact of the IL course. The distribution of pre- and post-test ILT scores for the TG2 is presented in **Figure 7**. The noticeable shift of the post-test scores to the right denotes higher IL achievements after the IL course.

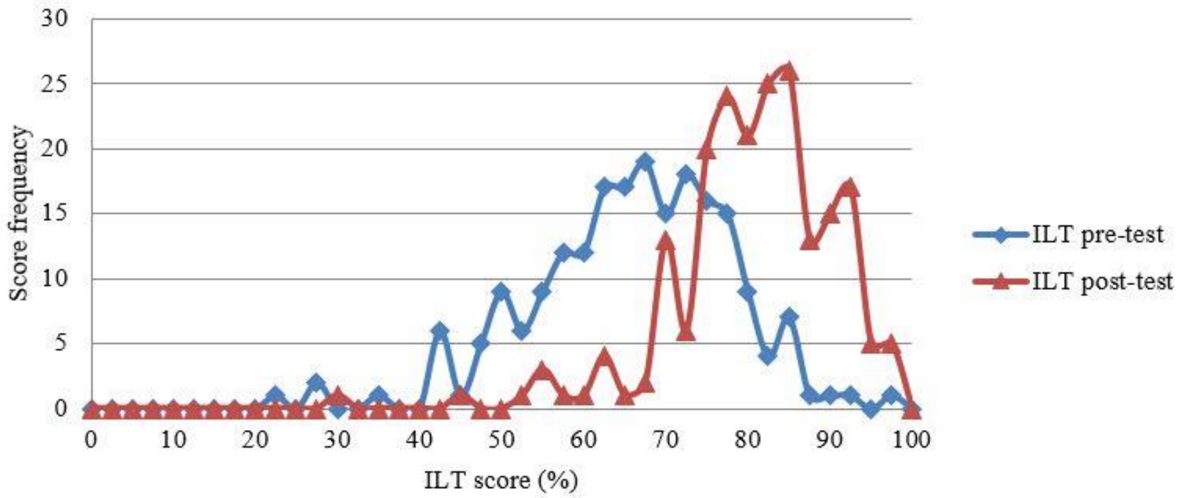


**Figure 7.** ILT pre-test and post-test score frequency (TG2, N = 205)

The differences between the pre- and post-test ILT scores in total and on subscale levels were investigated with the paired samples t-test (**Table 9**). There was a significant difference evident in the scores (%) of the pre-test (M = 65.9, SD = 12.07) and the post-test (M = 80.7, SD = 9.79). A similar trend was observed for all three cognitive categories, with the biggest mean difference being in the applying subscale (B3) (21.5%). All effect sizes were high, except for B3, which was moderate. The results indicated that completion of an IL credit-bearing study course significantly improved the students' IL in total and in each of the cognitive categories: remembering, understanding and applying of IL topics.

The ILT post-test results were also analysed with regard to the initial levels of IL and SL. The ILT pre-test and the post-test results correlated highly (r = 0.621); the significance level was $p < 0.001$. Assuming linear relationships, a moderate correlation was found between the SLT score and the ILT pre-test (r = 0.410), while the correlation was smaller between the SLT and the post-test (r = 0.279). The relationship is presented in **Figure 8**.

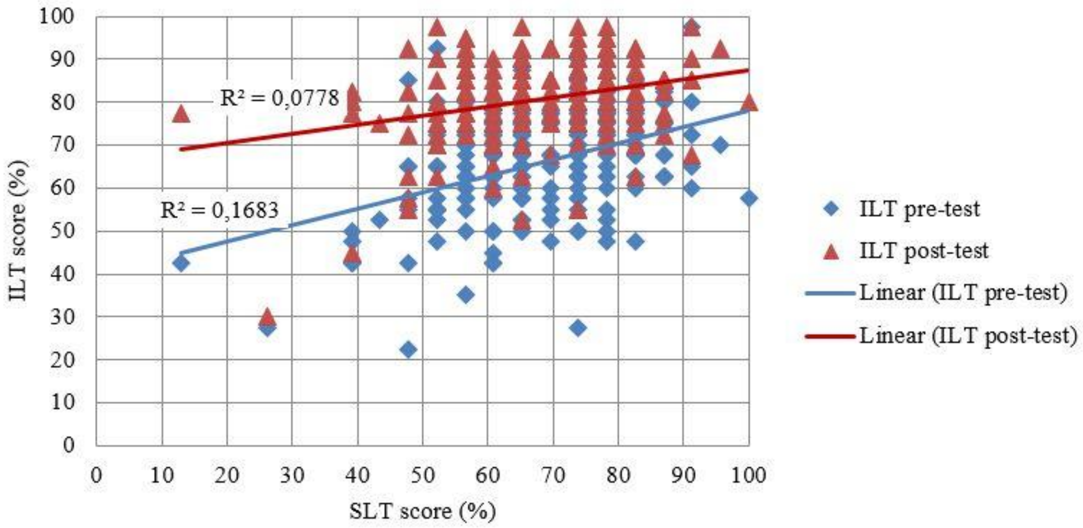


**Figure 8.** ILT pre-test/post-test score vs. SLT score with regression lines (N = 205)

This finding suggests that the IL intervention helped to reduce disparities between students.

In order to further assess the differences in IL levels with regard to SL, the students in TG2 were grouped into two subgroups: the TG2-b group with a below average SLT score (N = 104), and the TG2-a group with an above average SLT score (N = 101).

Both subgroups made significant post-test progress in all cognitive categories (**Table 10**), with the most progress (over 20%) evident in the highest category of knowledge application. The subgroups came particularly close in the lowest category of memorising, where they no longer differed significantly from each other.

**Table 10.** ILT pre-test difference and progress in the ILT post-test of the below-average (TG2-b) and above-average (TG2-a) groups according to SLT

| ILT | Pre-test diff TG2-a - TG2-b | Post-test progress TG2-b | Post-test progress TG2-a |
|---|---|---|---|
| Total | 6.9 | 16.3 | 13.3 |
| B1 | 6.3 | 15.2 | 10.5 |
| B2 | 5.7 | 12.7 | 11.0 |
| B3 | 9.3 | 22.9 | 20.1 |

The finding again speaks in favour of the observation that a well-designed IL course compensates for initial deficits and enables a higher level of IL and higher cognitive levels for all students.

## DISCUSSION AND CONCLUSIONS

The understanding of the terms IL, ICT literacy, digital literacy and SL is often vague in everyday academic communications, and the boundaries between them can be blurred. In the present study, IL was used in terms of an intellectual ability to recognise, locate, evaluate, use and understand information. In contrast, ICT and digital literacies were understood as sets of knowledge and skills related to various digital technologies, while the term SL was considered as a combination of knowledge, understanding and awareness of scientific concepts and processes. While ICT skills enable students to use software applications, computers and other technologies to better achieve educational, research, work-related and personal goals, IL augments students' competencies related to obtaining, evaluating, managing and using information. These skills and the associated knowledge can support scientific thinking, self-directed investigations and exploration, and can facilitate the solving of scientific research problems and contribute to lifelong learning.

To date, only a few studies (Berman, 2013a; Julien & Barker, 2009) have addressed the conceptual similarities between IL and SL. The present study found important parallels between the competencies and goals of IL and SL on the level of strategic background documents, matching the ACRL's IL standards to the OECD's PISA 2006 science competences.

Apart from studying the impact of integrated IL instruction on scientific knowledge, no quantitative research has been published on correlating IL and SL prior to formal IL instruction. The experimental part of the research therefore aimed to detect potential correlations between IL and SL in a group of university students. The findings obtained by a statistical analysis of the results led to the following conclusions related to the main research questions:

1. The level of IL and SL in the group of students before participating in an IL-specific course was fairly good, with a mean ILT score of 65.6%, and a mean SLT score of 67.1%.
2. The test results indicated a significant moderate positive correlation ($r = 0.487$) between the students' achievements in IL and SL.
3. A moderate positive correlation was also recorded between the students' cognitive levels of understanding and knowledge application in SL and the total IL level.
4. An active learning credit-bearing IL course had a statistically significant positive impact on the students' IL on all cognitive levels, with the biggest mean difference being recorded in their ability to apply IL knowledge (21.5%).

5. Two groups of students, one with a below average and one with an above average SL level, were both able to progress in a credit-bearing IL course with active learning elements and achieve a higher level of IL.

The positive correlation between the students' achievements in IL and SL confirms the existence of parallels between the ACRL IL standards, performance indicators and outcomes, and the SL competencies specified in PISA 2006. It is possible that students who were better at science prior to taking any formal IL instruction picked up certain basic IL skills during science lessons. Positive correlations between Bloom's cognitive levels of SL and overall IL level reflect the fact that both higher and lower order thinking skills are present in the ACRL IL outcomes. After participating in a credit-bearing IL study course, all of the students were able to achieve a higher level of IL, including those with a potentially lower initial level of SL. To speculate further, this could mean that a high level of IL is achievable for all students – those with a solid foundation in natural sciences, as well as those for whom SL is not their strongest attribute – if the study programme includes a well-designed IL course, in our case based on the ACRL standards and the related outcomes. This fact may be an incentive and justification for the inclusion of compulsory credit-bearing IL courses in university study programmes.

The finding of parallels and correlations between the SL and IL of university students may have further implications for education and research. We can hypothesise that the infusion of IL standards into all higher education science curricula, and into secondary-level educational science programmes, would positively affect the SL of students, as some research has already indicated (e.g., Bruehl et al., 2015). In addition, the introduction of IL active learning methods, also supported by the ACRL's revision of the IL standards for science and technology (Berman, 2013b), would support the higher-level cognitive skills that are needed for successful problem solving, and for students' ability to differentiate between evidence-based scientific explanations and personal opinions. However, further research and additional studies are needed to explore these assumptions.

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