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ROLE AND MEANING OF FUNCTIONAL SCIENCE, TECHNOLOGICAL AND ENGINEERING LITERACY IN PROBLEM-BASED LEARNING

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Abstract. *Literacy, in particular functional literacy in various fields and especially in the field of STEM, is becoming an increasing problem in modern-day society. The question arises, can the school system develop the kind of functional literacy in students, which allows them to fulfil, in real life, their personal and professional needs related to the competence of reading and creating written texts from the field of science, technology and engineering?*
The present research aimed to explore how students in today's schools are trained in functional literacy, especially in the fields of technology and engineering, and what kind of literacies in the field of STEM they are able to (or should be able to) master competently. The present research showed that students achieve relatively poor results in the area of functional literacy, both regarding their science literacy, and especially their technology and engineering literacy, which is a result of a lack of competence on behalf of mother-tongue teachers to develop this kind of functional literacy. Functional literacy should be developed by teachers of individual areas of STEM subjects.
Keywords: *engineering functional literacy, functional literacy, key competence, problem solving, science functional literacy.*

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Introduction

In today's society literacy, especially functional literacy, is becoming a serious issue (OECD, 2000, PISA, 2015). Today's society requires the educational system to train as many people as possible to achieve higher cognitive ways of thinking (OECD, 2009, 2011, 2014), therefore it is necessary to take into consideration the distinctive features of the educational field, where the student is not only the object of teaching but also the subject of its own control and change, and structuralism as the fundamental premise must be replaced with *cognitive science* (Bermudez, 2010, Aberšek, Borstner & Bregant, 2014). It should be emphasized that acquiring knowledge is a complex and deliberate process, in which conclusions, summaries and predictions are formed, and the knowledge acquired in this way enables the anticipation of situations and the choice of appropriate reactions in these situations. The starting point for cognitive psychologists in trying to provide answers to the questions of how the human brain memorizes and learns, therefore, is to look for an internal mechanism that controls human thinking and the acquisition of knowledge, whereby functional literacy is of key importance (OECD, 2000, PISA, 2015, PIRLS, 2016).

In today's science, reading is understood as an active process in which the reader constructs meaning from a text by assimilating information from the text with their existing background knowledge and previous knowledge about the subject of the text. In doing so, sophisticated readers apply a number of cognitive strategies (Fisher, Frey & Lapp, 2009) in order to decide what is important for them in the text, organize what they have read into networks of hierarchical concepts, relate new knowledge to what they already know, and evaluate what they have read. These strategies include: asking questions, developing connections, and, which is especially important, creating *inferential bridges,* which refer to the forming of logical connections between information in the text (Aberšek et al, 2017).

There is no doubt about the above mentioned in the science of reading, and so the question arises, to what extent school curricula are able to develop such reading competence in students. It seems, namely, that school systems are still not done away with the idea of functional literacy as a relatively monolithic competence. In today's world, every expert/scientific field has developed its own specific text types. Consequently, for studying chemistry, biology and physics textbooks (e-textbooks), specific functional literacies are needed. The same could be established for studying engineering and technical texts. For these, too, the reader/student needs specific functional literacies. All these literacies are covered when speaking about functional literacy in the field of STEM.

STEM Literacy/STEM Literacies

STEM literacy is a term which became topical in the last few decades, as it becomes more and more apparent that general functional literacy at higher levels overlaps with competences of the so-called subject-specific (content area) literacies. This doctrine focuses on science, engineering and technological literacy (STE literacy), which encompasses ethical use of science, knowledge about the rules of science, technology and engineering, and the ability to understand and use engineering and technology as applied sciences. Being a relatively new term, *STEM literacy* is still to be defined precisely. One of the most frequently used definitions is the following: "STEM literacy is the ability to identify, apply, and integrate concepts from science, technology, engineering, and mathematics to understand complex problems and to innovate to solve them" (Balka, 2011: 7).

Such an understanding of STEM literacy, however, appears too narrow, as it focuses primarily on the scientific and developmental engineering aspect of STEM literacy. From the perspective of the general population and the idea of lifelong learning (which is necessary in the fields of engineering and technology, as these two disciplines are evolving at an exponential rate and have a crucial impact on an individual's everyday life), and, of course, for the purpose of education and acquiring knowledge and competence in schools, the above definition is incomplete for at least two reasons:

- because it is based on the assumption about a single type of functional literacy, which should therefore apply to all natural science disciplines (from biology to chemistry, physics, applied science, etc.), and
- because it fails to include the notion of competences, related to literacy in the strict sense of the word, i.e., the ability to communicate about scientific phenomena in general, and especially the ability to communicate through the written channel.

The problem arising from the assumption about STEM literacy as a monolithic competence was quickly noted, and soon after the turn of the millennium definitions of literacy began to emerge that relate to the individual scientific disciplines/areas of the acronym STEM. Zollman (2012) defined four types of literacies: scientific literacy, mathematical literacy, engineering literacy and technological literacy. In this context he described *engineering literacy* as the ability to systematically and creatively apply scientific and mathematical principles to practical ends such as the design, manufacture, and operation of efficient and economical structures, machines, processes, and systems (OECD, 2011a). And he described *technological literacy* as the ability to demonstrate creativity and innovation, communicate and collaborate, conduct research and use information, think critically, solve problems, make decisions, and use technology effectively and productively (ISTE, 2000).

At the end of the second decade of the new millennium, therefore, it seems that science can no longer refer to one single STEM literacy, but rather to several *STEM literacies.* While science, mathematical, engineering and technological literacy may well refer to competences sharing common roots and a set of common attributes, they are ultimately different kinds of literacy competences, which serve different goals, lead to different results and must therefore be developed systematically, each of them separately (Zollman, 2012).

The above-mentioned definition of technological literacy, as developed by the International Society for Technology and Education, is a step closer to the solution of the second problem, which was mentioned in relation to the original definition of STEM literacy. It focuses attention on the process of knowledge acquisition, as the term "ability to communicate" the knowledge and problem solutions in the field of technology suggests that today students acquire information and comprehensive knowledge (at school) mainly by looking for it in relevant sources.

This kind of teaching is the only way to achieve the goals mentioned in the definition of engineering and technological literacy, namely, to develop creativity and innovation, to collaborate and to conduct research in the framework of solving didactical problems by using technology effectively and productively. Because of this, in problem-based learning situations students can develop the ability to independently deal with science, engineering

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and technology-related texts, the ability to understand such texts, and also the ability to use and critically evaluate them. In other words, in a problem-solving oriented didactic approach to technical education, students need to develop their technological and engineering literacy in a stricter communication-related sense of the word – what they need is *functional literacy in the field of engineering and technology*.

At first glance, it seems that everything is now in place, the school curriculum will enable students to become *literate* in all areas covered by the curricula of their elementary and further education. But a more detailed reflection quickly points to some issues. The initiator of developing *disciplinary literacies* (and in this context, also STEM literacies) is the International Literacy Association, ILA (formerly the International Reading Association). The ILA primarily addresses L1 teachers (teachers of mother tongue) by providing them with "a set of guidelines for the implementation of the English Language Arts Common Core State Standards. Among these guidelines are recommendations for the use of challenging texts, teaching basic skills (such as phonological awareness and fluency), focusing on comprehension, and developing writing skills and acquiring disciplinary literacy" (IRA, 2012). The problem in this context is not the purpose of *developing disciplinary literacies*, but in *defining what a challenging text is* in the field of the individual discipline. Or, more specifically, to what extent can mother-tongue teachers understand and critically evaluate demanding texts from the fields of physics, chemistry, engineering, technology? Believing that this could be done by mother-tongue teachers who definitely do not possess enough knowledge in the areas of physics, chemistry, engineering, or technology, is simply naive.

The present research focused on the problem of STE(M) literacy in the Slovene compulsory school curriculum. *The central research question* was the question of whether a L1 teacher (mother-tongue teacher), who is responsible for developing general functional literacy, can also develop particular functional literacies. The question was analysed on the case of science, technology and engineering literacy (STE). In this research functional literacy in the field of engineering and technology (and, by way of analogy, also in other fields) is understood as:

1. *Information literacy in the field of STE*, which is defined as the ability to find and manage information, and the ability to critically evaluate and ethically apply that information to solve a problem;
2. *Functional reading literacy in the field of STE*, which refers to
    - reading an *expository and explanatory text* from the field of (S)TE, understanding it (in the verbal and visual code), and using the knowledge acquired in this way to solve problems,
    - reading/writing text types such as *description of a procedure, instructions for use, building or manufacturing instructions,* understanding such texts and use what was read to successfully and safely use a new product, make a product, assemble furniture, etc. (Aberšek, et al., 2014, Dolenc, Aberšek, Kordigel Aberšek, 2015).

"In today's world, to be literate requires students to be able to use and understand vocabulary specific to each domain, to critically interpret and analyse multiple types of texts, and to express those understandings in creative ways" (Lefever-Davis, Pearman, 2015). This kind of literacy, as defined by Lefever-Davis and Pearman, cannot be taught by mother-tongue teachers, despite the fact that teaching reading and writing (of all kinds of texts) is their responsibility in the majority of existing school systems. As results of this research point out, the mother tongue-teacher does not have the competence to develop all STEM literacies.

Methodology of Research

General Background

Of particular interest to this research was the question of how worldwide education systems, in which only mother-tongue teachers are responsible (as part of implementing the mother tongue and literature curriculum) for the development of reading/learning strategies and functional reading, meet the requirements for functional literacy in the field of STE. As part of the research, the reading speed and reading comprehension of technical expository texts and procedural texts (instructions for use and manufacturing instructions), was measured. The target groups in this research were primary school students of the sixth and seventh grades (age 13-14 years). At this age, students should already be able to use reading to search for information, read critically and learn independently with the help of reading.

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The main objectives of this research were:

- To analyze the state of reading comprehension and the speed of reading of *expository texts* from the field of engineering and technology;
- To analyze the state of reading comprehension and the speed of reading of *manufacturing instructions for a product*;
- To analyze the comparison of the state of reading comprehension and reading speed between the two types of texts;
- To analyze the state of reading comprehension and reading speed and use it as a basis for defining the level of (S)TE functional literacy.

The basic research method applied was mainly a quantitative method of pedagogical research, while a survey and action research were used to collect data. Basic information about the students was obtained through the use of a questionnaires and a non-experimental research.

Sample Selection

The pilot research was carried out in classes of 'Science and Technology' (ST classes), as part of a thematic area called 'Making products from paper materials'. Science and Technology is a compulsory subject in Slovene compulsory education and is taught in the sixth, seventh and eighth grades. The pilot research included 108 students from a smaller town, settled in a peripheral region in Slovenia, who attended the sixth or seventh grade at the same primary school in the school year 2017/2018. Out of these, 68 were students of three divisions of the sixth grade (63%) and 40 were students of two divisions of the seventh grade (37%). There were 18 more sixth-grade students in comparison to the number of seventh-grade students (16.7%). According to gender, 55 boys (51%) and 53 girls (49%) were included in the research.

Procedures and Instruments

The research measured the reading speed, reading comprehension and effective reading speed of reading *technical expository texts* and *manufacturing instructions*. Students' knowledge and the efficiency of their work were tested by quantitatively measuring and calculating (according to eq. 1 and 2) reading time and reading understanding for *expository texts* and for *manufacturing instructions* in the field of engineering and technology education. The research task was the analysis of overall results in reading speed and understanding of technical expository texts and manufacturing instructions, which provided an insight into the level of functional technological and engineering literacy on the sample included in this survey.

Regarding the analysis of reading speed, the research presented:

- types of readers from the perspective of the speed of reading technical expository texts, manufacturing instructions, and reading both text types,
- differences in reading speed from the perspective of reading technical expository texts, manufacturing instructions, and both text types.

The students were also tested for their effective reading speed, which depends on the number of read words per minute and the degree of understanding the read text. The research presented:

- types of readers from the perspective of effective reading speed in reading a technical expository text, manufacturing instructions, and both text types,
- differences in effective reading speed when reading a technical expository text, manufacturing instructions, and both text types.

After discussing and coordinating with teachers of the school subject 'Slovene language and literature', students learned about different reading strategies on a variety of examples in their mother-tongue classes. After learning different reading strategies, a questionnaire was carried out in order to identify the existing situation – the ability of transferring the general functional literacy acquired in mother-tongue classes to the level of functional literacy in the field of engineering and technology. Using scientific measuring instruments, the reading time and understanding of texts was measured, and the effective reading speed was calculated.

In order to test the speed of reading and reading comprehension, a questionnaire for different difficulty levels was prepared. The questions were related to the technical expository text and the manufacturing of the product. To

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evaluate the students' responses and measure the reading time, an expert evaluation group was created, consisting of two engineering and technology teachers and two mother-tongue teachers.

The expert evaluation group reviewed the student's answers to the posed questions, which were related to reading technical expository texts and manufacturing instructions. The degree of correctness of the answers was coordinated by the evaluation group following a mutual consultation. In order to ensure objectivity, the questionnaire contained only basic information about the student (student identification number, gender and grade). In this way, members of the evaluation group were unable to include any personal views in the evaluation of the students' responses. This expert evaluation group also participated in the preparation of the questionnaire for measuring reading speed, reading comprehension and effectiveness of reading, which were adopted from international studies such as OECD, PIRLS, PISA (OECD, 2000, 2011, 2014, PIRLS, 2016, PISA 2006, 2015), thus ensuring the validity of the scientific instrumentation used. The measuring instrument contained three main sets.

1. Student information (gender, grade)
2. Reading speed test and text comprehension test:
   - speed of reading (HBS) and reading comprehension (VBS) test for a technical expository text,
   - speed of reading (HBN) and reading comprehension (VBN) test for instructions for manufacturing a product,
3. Speed and effectiveness of reading technical expository texts (EBS) and manufacturing instructions for a product (EBN).

Data Analysis

The reading speed was tested by measuring the time needed to read a technical expository text and the time needed to read manufacturing instructions for a product. All the students began to read at the same time. As the students finished reading, the precise time was checked, and the measurements (individual reading times) were recorded. The number of read words per minute was calculated by calculating the quotient between the number of words in the text and reading time in minutes:

$$\text{Number of read words per minute} = \frac{\text{Number of words in the test}}{\text{Reading time (in minutes)}} \quad (1)$$

On the basis of studying relevant literature (Buzan, 2009; Schmitz, 2012), groups (types) of readers were formed according to the number of words read per minute. When forming the groups, the students' age, their level of development and the difficulty level of the text were also taken into account. Depending on the degree of difficulty of the text and the age of readers, they were categorized into four groups (Table 2).

Table 2. Types of readers according to the number of words read per minute (adapted from Buzan, 2009; Schmitz, 2012).

	Reader	Reading speed (wpm)
1.	Very slow	up to 49
2.	Average	from 50 to 79
3.	Fast	from 80 to 110
4.	Very fast	above 111

Since in addition to being fast, a good reader also has to be good at understanding and remembering what they read, the number of read words per minute (Table 2), and the percentage of correct answers (Table 3), were used to calculate the effective reading speed (the product of the number of read words per minute and the percentage of correct answers), on the basis of which four types of readers were discerned (Table 4).

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$$\text{Efective reading speed} = \frac{\text{Number of words per minutes x \% of correct answers}}{100} \quad (2)$$

Table 3. Types of readers according to the level of text understanding.

Number	Reader	Understanding (%)
1.	Poor	up to 44%
2.	Average	from 45% to 60%
3.	Functionally literate	from 61% to 75%
4.	Very good	above 76%

Table 4. Types of readers according to effective reading speed.

Number	Reader	Effective reading speed
1.	Poor	up to 22.5
2.	Average	from 22.6 to 48
3.	Functionally literate	from 48.1 to 82.5
4.	Very good	above 82.6

The level of understanding in reading technical expository texts and manufacturing instructions was tested using questions related to the text that was read.

1. Reading a technical expository text

The text for testing the speed of reading and reading comprehension of technical expository texts contained 682 words and 10 photographs. The text included a description of the procedure for making a wheat starch paste adhesive, information about paper materials, and 9 words, which were new to six-grade students.

2. Reading manufacturing instructions

The text contained 568 words with added 32 photographs showing the tools and materials needed for making (manufacturing) the product and the individual phases of the procedure.

According to the total number of points achieved and the difficulty level, the expert evaluation group was designed, based on a comparison with rating scales of other expert teams, a four-level scale to measure the practical understanding of manufacturing instructions was formed (Table 5).

Table 5. Types of readers according to connection between theory and practice.

	Reader	Percentage of acquired points (v %)
1.	Poor	up to 50%
2.	Satisfactory	from 51% to 70%
3.	Good	from 71% to 90%
4.	Very good	above 91%

Microsoft Excel 2016 was used to organize the obtained data. For the statistical processing of the organized data, the SPSS 22.00 software package was used.

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Research Results

The research results, i.e., reading speed, reading comprehension and effective reading speed of reading technical expository texts and manufacturing instructions, are presented in this chapter.

Analysis of Reading Speed

The comparison between the speed of reading a technical expository text and the speed of reading manufacturing instructions is shown in Table 6.

Table 6. Wilcoxon signed-rank test for reading a technical expository text and manufacturing instructions

Reading speed (HB_)		Instructions HBN – technical expository text HBS	Mean rank
Arithmetic mean difference (N in %)	HBN < HBS	78.7	55.33
	HBN > HBS	21.3	51.43
	HBN = HBS	0	
Z		- 5.40	
Asymp. Sig (*p*) (2-tailed)		.0001	
Reading comprehension (VB_)		**Instructions VBN– technical expository text VBS**	**Mean rank**
Arithmetic mean difference (N in %)	VBN < VBS	45.37	52.39
	VBN > VBS	54.62	56.25
	VBN = VBS	0	
Z		-1.152	
Asymp. Sig (*p*) (2-tailed)		.249	
Effective reading speed (EB_)		**Instructions EBN– technical expository text EBS**	**Mean rank**
Arithmetic mean difference (N in %)	EBN < EBS	49.07	58.73
	EBN > EBS	50.93	50.43
	EBN = EBS	0	
Z		-0.520	
Asymp. Sig (p) (2-tailed)		.603	

Legend:
HBS - Reading speed of technical expository text; HBN - Reading speed of instructions for manufacturing a product.
VBS - Reading comprehension for a technical expository text; VBN - Reading comprehension for instructions for manufacturing a product.
EBS - Effectiveness of reading technical expository texts; EBN - Effectiveness of reading manufacturing instructions for a product.

Figure 1 shows types of readers according the speed of reading two types of texts, namely, technical expository texts and manufacturing instructions, and also the average speed of reading both text types.

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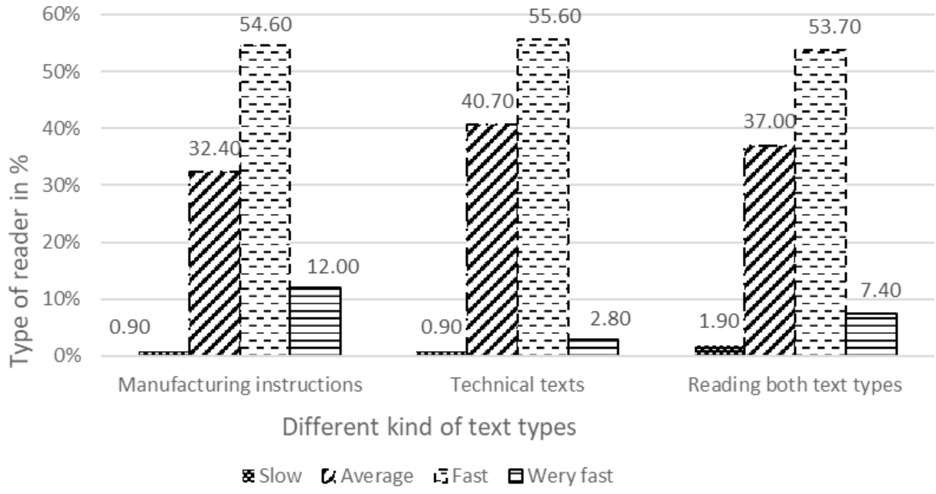

Figure 1. Types of readers according the speed of reading technical expository texts and manufacturing instructions and average speed of reading both text types.

Table 7 shows statistical values of reading speed.

Table 7. Results of reading speed.

Reading speed	Technical expository text	Manufacturing instructions	Total
Arithmetic mean	88.54	82.42	85.48
Standard deviation	17.08	14.88	14.92
Minimum	39.92	48.48	47.01
Maximum	121.07	120.85	120.55
I. quartile (Q1)	71.71	71.08	73.83
Median	84.81	83.23	86.61
III. quartile (Q3)	99.08	91.43	94.31

Table 8 shows the correlation between the speed of reading technical expository texts, manufacturing instructions, and both text types.

Table 8. Spearman's correlation coefficient for the speed of reading technical expository texts, manufacturing instructions, and both text types.

Reading speed		Technical expository text	Manufacturing instructions	Total
Technical expository text	Spearman's correlation coefficient	1	.730	.930
	Asymp. Sig. (p) (2-tailed)	/	.0001	.0001
Manufacturing instructions	Spearman's correlation coefficient	.730	1	.920
	Asymp. Sig. (p) (2-tailed)	.0001	/	.0001

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Analysis of Reading Comprehension

Based on the Wilcoxon test for comparing reading comprehension in students (Table 6), there was no statistically significant difference regarding the percentage of achieved points and in turn, regarding the reading comprehension, between technical expository texts and manufacturing instructions ($p = .249$). This is true in spite of the fact that 45.37% of students achieved a higher number of points for their understanding of a technical expository text, and 54.62% of students achieved better results for understanding manufacturing instructions. The mean rank for reading a technical expository text was 52.39% of achieved points, and 56.25% of achieved points for reading manufacturing instructions.

Types of readers according to their understanding of a technical expository text, manufacturing instructions, and both text types, are shown in Figure 2.

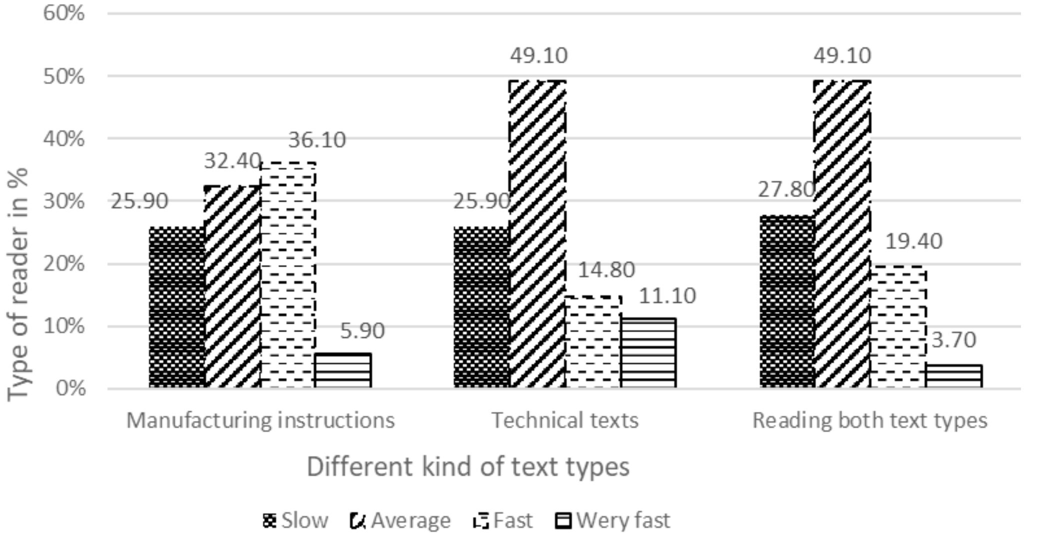

Figure 2. Types of readers according to their understanding of a technical expository text, manufacturing instructions, and both text types

Regarding the level of understanding what was read in a technical expository text, 25% of the students were poor readers, and 25.90% of students were poor readers with regard to their reading comprehension of manufacturing instructions. From the point of view of reading comprehension of both text types, 27.80% of the students were labelled as poor readers. These were students who achieved up to 45% of possible points in answering questions about the read text (Figure 2). The percentage of average readers was also smaller, by 16.70%, with regard to reading comprehension of manufacturing instructions in comparison to understanding what was read in a technical expository text (32.40% average readers for manufacturing instructions; 49.10% average readers for technical expository texts). The percentage of good readers was larger in the case of reading manufacturing instructions (36.10%) than in the case of reading a technical expository text (14.80%). With regard to reading comprehension of a technical expository text, 11.10% of the students were very good readers, and only 5.60% of the students were very good readers in the case of understanding what was read in manufacturing instructions. These were students who achieved between 60% and 75% of possible points (good reader), or more than 75% of points (very good reader) when answering questions about the read text.

From the perspective of reading comprehension of both text types, 27.80% of the students were poor readers, 49.10% were average readers, 19.40% were good readers, and only 3.70% were very good readers.

In comparison to the level of understanding a technical expository text, the students achieved better results (2.06% higher on average) in the case of reading and understanding manufacturing instructions (Table 9). The average percentage of achieved points after reading a technical expository text was 50.53% of the maximum number of

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points, and 52.59% in the case of reading and understanding manufacturing instructions. After reading a technical expository text, the top 25% students (Q_4) achieved, on average, more than 60,32% of possible points, and more than 64.32% of points in the case of manufacturing instructions. For technical expository texts, the lowest-scoring 25% of students (Q_1) achieved up to 39.88% of the maximum number of points, and up to 39.58% of points (poor readers) in the case of manufacturing instructions.

From the perspective of reading comprehension of both text types, the students achieved an average of 51.42% of possible points. The bottom 25% *(Q_1)* achieved between 16.22% and 43.69% of the maximum number of points (poor readers) with respect to reading and understanding both text types. The top 25% of students *(Q4)* achieved between 59.46% and 83.33% of points after reading both text types (average to very good readers).

Table 9. Results of the analysis of reading comprehension for technical expository texts, manufacturing instructions and both text types.

Reading speed	Technical expository text	Manufacturing instructions	Total
Arithmetic mean	50.53	52.59	51.42
Standard deviation	16.98	17.58	13.14
Minimum	9.22	9.38	16.22
Maximum	89.68	91.67	83.33
I. quartile (Q1)	39.88	39.58	43.69
Median	48.02	57.29	52.48
III. quartile (Q3)	60.32	64.32	59,46

Spearman's rank correlation coefficient (Table 10) was used to determine the relation between reading comprehension and reading speed. The research established that there was a slight statistically significant positive correlation between the achieved percentage of points when reading manufacturing instructions and the speed of reading a technical expository text (r = .190, p = .049); between the speed of reading both text types and the percentage of achieved points when reading manufacturing instructions (r = .192, p = .047)*;* and a borderline statistically significant correlation between the speed of reading manufacturing instructions and the percentage of achieved points in the reading comprehension of manufacturing instructions (r = .163, p = .092). The test further confirmed that there was a strong statistically significant correlation between the percentage of achieved points after reading both text types and the percentage of achieved points after reading manufacturing instructions (r = .652, p = .0001), and a very strong statistically significant correlation between the percentage of achieved points after reading a technical expository text and the percentage of achieved points after reading both text types (r = .805, p = .0001).

Table 10. Results of reading comprehension.

Reading comprehension		Technical expository text	Manufacturing instructions	Total
Technical expository text	Spearman's correlation coefficient	1	.132	.805
	Asymp. Sig. (p) (2-tailed)	/	.173	.0001
Manufacturing instructions	Spearman's correlation coefficient	.132	1	.652
	Asymp. Sig. (p) (2-tailed)	.173	/	.0001
Reading speed for t. expository text	Spearman's correlation coefficient	.018	.190	.085
	Asymp. Sig. (p) (2-tailed)	.856	.049	.384

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Reading comprehension		Technical expository text	Manufacturing instructions	Total
Reading speed for manufacturing instructions	Spearman's correlation coefficient	- .059	.163	.034
	Asymp. Sig. (p) (2-tailed)	.546	.092	.728
Reading speed for both text types	Spearman's correlation coefficient	-.009	.163	.034
	Asymp. Sig. (p) (2-tailed)	.924	.092	.728

Analysis of Effective Reading Speed

Based on Wilcoxon's criterion for comparing the effective reading speed when reading a technical expository text and when reading manufacturing instructions (Table 6), it was found that 49.07% of the students achieved a higher effective reading speed when reading manufacturing instructions, and 50.93% when reading a technical expository text. The negative z-score (Z = - .520) implied that there were more negative differences than positive ones, i.e., that more often the students achieved a higher effective reading speed when reading manufacturing instructions, however, this difference was not a statistically significant one (p = .603).

Types of readers according to the effective reading speed when reading a technical expository text, manufacturing instructions, or reading both text types, are shown in Figure 3. Measuring the effective reading speed in reading technical expository texts showed that 7.40% of the students were poor readers. These were students whose answers to the questions about the read text were insufficient, and their reading speed was low (small number of read words per minute). In the case of reading manufacturing instructions, there were 14.80% of poor readers. In comparison, there were also more (by 14.90%) average readers in the case of technical expository texts (55.60%) than in the case of manufacturing instructions (40.70%). There were 9.20% less of good readers of technical expository texts (34.30%) in comparison to the percentage of good readers of manufacturing instructions (43.50%). In addition, it was measured that 2.80% of the students achieved very good results in reading a technical expository text (effective reading speed above 82.5), and 0.90% were very good readers in the case of reading manufacturing instructions.

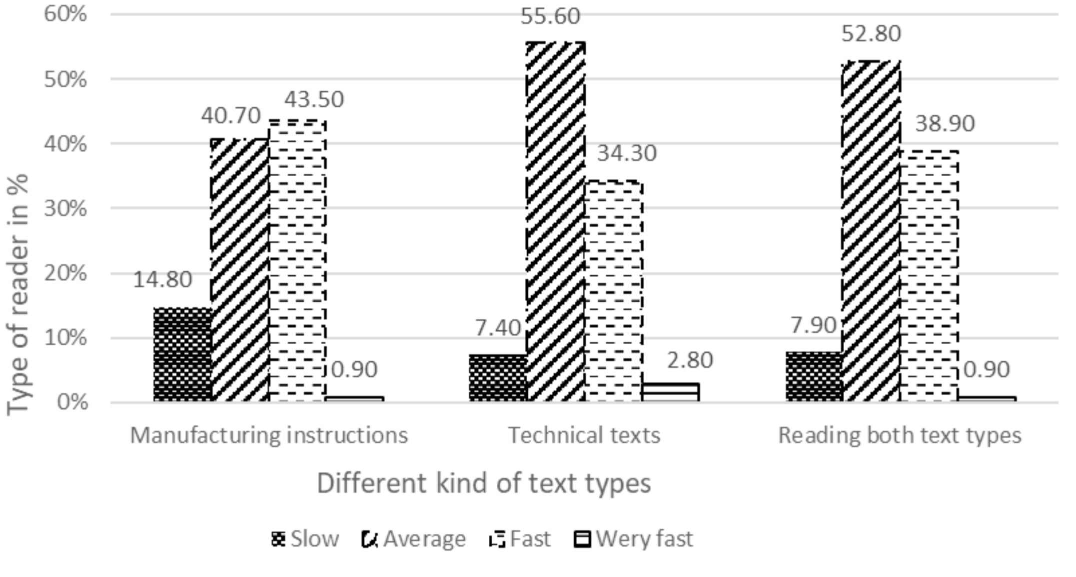

Figure 3. Types of readers according to effective reading speed.

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When reading a technical expository text, the students reached an average effective reading speed of 44.84 (Table 11), and an average effective reading speed of 43.69 (average reader) when reading manufacturing instructions. The individual student's effective reading speed for technical expository texts deviated from the average effective reading speed by a standard deviation of 17.80, and by a 17.00 standard deviation in the case of manufacturing instructions. 25% of the students with the lowest score *(Q_1)* reached effective reading speeds between 7.6 and 33.34 when reading a technical expository text; and between 7.61 and 30.38 when reading manufacturing instructions (poor reader – average reader). 25% of the highest-scoring students *(Q4)* reached an effective reading speed for technical expository texts between 55.09 and 99.85, and an effective reading speed for manufacturing instructions between 56.88 and 85.00 (good – very good reader).

From the point of view of reading both text types, the average effective reading speed was 44.11. The individual student's effective reading speed deviated from the average effective reading speed by a standard deviation of 13.98. 50% of the students reached effective reading speeds lower than 43.23 (poor – average readers). The bottom quarter *(Q_1)* reached effective reading speeds between 12.92 and 35.23, while the top 25% of the students *(Q_4)* reached an effective reading speed between 52.51 and 85.91 of read words per minute.

Table 11. Results of effective reading speed.

Reading speed	T. expository text	Manufacturing instructions	Total
Arithmetic mean	44.84	43.69	44.11
Standard deviation	17.80	17.00	13.98
Minimum	7.60	7.61	12.92
Maximum	99.85	85.00	85.91
I. quartile (Q_1)	33.34	30.38	35.23
Median	42.60	45.11	43.23
III. quartile (Q_3)	55.09	56.88	52.51

Below, the results of the Spearman correlation test (Table 12) are presented, which was used to measure the correlation between the effective reading speed of a technical expository text, the effective reading speed of manufacturing instructions, and the effective reading speed when reading both text types.

Table 12. Spearman's correlation coefficient for effective reading speed.

Effective reading speed		Expository text	Manufacturing instructions	Total
Expository text	Spearman's correlation coefficient	1	.258	.795
	Asymp. Sig. (*p*) (2-tailed)	/	.007	.0001
Manufacturing instructions	Spearman's correlation coefficient	.258	1	.767
	Asymp. Sig. (*p*) (2-tailed)	.007	/	.0001

It was established that a weak positive statistically significant correlation existed between the effective reading speed of manufacturing instructions, and the effective reading speed of a technical expository text (r = .258, *p* = .0001); a strong (very strong) correlation existed between the effective reading speed of a technical expository text (r = .795, *p* = .0001) and the effective reading speed of reading both text types; and a high statistically significant correlation existed between the effective reading speed of manufacturing instructions and the effective reading speed of both text types (r = 0767, *p* = .0001) – those students, who had higher effective reading speeds when reading manufacturing instructions, also had a higher reading speed in the case of reading a technical expository text, as well as a higher effective reading speed considered from the perspective of reading both text types.

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Discussion

In this research, the notion of *functional literacy in the field of engineering and technology* was defined, and the specifics of reading competence and the concept of understanding technical texts from the field of engineering and technology were described. A relevant circumstance in this research was the fact that in Slovenia, developing functional literacy is the responsibility of mother-tongue teachers as part of the curriculum in the framework of the school subject called 'Slovene language and literature'. The research focused on the following question: is it realistic to expect of mother-tongue teachers to develop in the mother-tongue class functional literacies for reading so-called "demanding texts" from the field of engineering and technology? The results of the present research provide a rather straightforward answer. A comparison between the types of readers according to the type of text they were asked to read, shows that both in the case of reading a technical expository text, as well as in the case of reading manufacturing instructions (Figure 1), there were 0.90% of slow readers (reading up to 50 words per minute – Table 3). Table 3 also shows that, regarding the reading of manufacturing instructions, there were 32.40% of average readers (reading between 50 and 80 words per minute), 54.60% of fast readers (reading between 80 and 110 words per minute), and only 12% of very fast readers, who read more than 110 words per minute. In the case of reading a technical expository text, however, there were more average readers (40.70%) and fast readers (55.60%), and less very fast readers (2.80%). From the point of view of the speed of reading both text types, there were 1.90% of slow readers, 37% of average readers, 53.70% of fast readers, and 7.40% of very fast readers. A comparison of reading speed between technical expository texts and manufacturing instructions (Table 6), shows that 78.70% of the students reached a higher reading speed when reading a technical expository text, while 21.30% of the students were faster when reading manufacturing instructions. The mean rank for reading a technical expository text was 55.33 read words per minute, and 51.43 read words per minute in the case of manufacturing instructions (on average, students read 3.9 words per minute more when reading a technical expository text than they did when reading manufacturing instructions). On the basis of the calculated Z-score ($Z = -5.40$) and the asymptote significance value ($p = .0001$ ($p < .05$)), it was concluded that there were statistically significant differences between the reading speed when reading a technical expository text and the reading speed when reading manufacturing instructions. The standard deviation of the number of read words per minute from the average (Table 7) was 14.88 read words per minute in the case of reading a technical expository text. The average reading speed when reading a technical expository text was 88.44 words per minute and 82.42 words per minute when reading manufacturing instructions. Students who scored in the bottom 25% read between 39.92 and 71.71 words per minute on average when reading a technical expository text (between 48.48 and 71.08 words per minute on average when reading manufacturing instructions). Students who scored in the top 25% read between 99.08 and 121.07 words per minute on average when reading a technical expository text (between 91.43 and 120.85 words per minute on average when reading manufacturing instructions).

The reading speed results for both text types tell the same tale (Table 7): the average reading speed calculated on the sample was 85.48 of read words per minute for technical expository texts. The individual student's reading speed deviated from the average by 14.92 of read words per minute. Students who scored in the bottom 25% read between 47.01 and 73.83 words per minute. Students who scored in the top 25% read between 94.31 and 120.55 words per minute.

Concerning the reading speed for technical expository texts, manufacturing instructions, and both text types, the Spearman correlation coefficient (Table 8) implies a very high statistically significant positive correlation between reading a technical expository text, reading manufacturing instructions, and reading both text types ($r = .930$; $r = .920$), and a high correlation between the reading speed when reading a technical expository text and the reading speed when reading manufacturing instructions ($r = .730$).

These results serve as persuasive arguments in answering the question of *whether a mother-tongue teacher can successfully teach science, technology and engineering literacy. The answer, of course, is no*. Students can learn the majority of elements of the engineering and technical language only from their subject teacher of technology. Generally, teachers should be able to teach them to read two types of texts: expository and explicatory texts from the field of engineering and technology (definition, description, comparison – contrast, cause – effect, problem – problem solution, and description of the process), and procedural texts describing processes (instructions for use, manufacturing instructions). These are two key types of texts, which basically differ in the significance of the concept of time for understanding the text and for successfully using the information from the text (i.e., the chronological sequence of information). It depends on the latter whether the student/reader will be able to achieve the goal of

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reading, more specifically, whether they will be able to solve the problem posed (by themselves or by the teacher) before the reading. According to the definition of engineering literacy, students should be able to demonstrate creativity and innovation, communicate and collaborate, conduct research and use information, think critically, solve problems, make decisions, and use technology effectively and productively (ISTE, 2000).

The research clearly shows that problems exist regarding literacy, especially functional literacy, which has been confirmed also by the findings of most other (international) studies in this area. It is a task for education to foster awareness of the fact that teaching literacy is not only the duty of mother-tongue teachers, but also, especially with regard to functional literacy, a responsibility of teachers of individual expert areas – in the case of the present research, science and technology teachers. In order to achieve this, the following is recommended:

1. Collaboration between the mother-tongue teacher and the subject teacher – the objective is *developing functional literacy*, which is carried out at the school level, however, the entire education chain should also be included in this process, including the competent ministry, research institutions, schools that train educators, as well as educational institutions themselves (primary schools, secondary schools, universities).
2. Training teachers for collaborative forms of work. At the same time, this principle (cross-curricular cooperation and communication) should also be introduced at a global, paradigmatic level.
3. Development of strategies for collaborative and research learning with an emphasis on methods for independent reading to support innovative approaches to research and collaboration, which, with the emergence of technology in schools, are no longer an option, but a necessity.

Conclusions

It is evident from the present research that in schools, a shift from understanding functional literacy as a monolithic competence to so-called functional literacies in subject-specific fields, is required. Functional literacies in individual subject areas can only be the result of cross-curricular co-operation between a teacher of the Slovene language (i.e., mother-tongue teacher) and a subject teacher, or teachers, with the share of responsibility leaning towards the latter as the level of education progresses. It should be remembered, of course, that only properly qualified teachers are able to competently perform their role in this process. Therefore, teachers need to be trained in at least two areas, namely, in the field of functional literacy, in this case STE functional literacy, and in collaborative work. In order to achieve this, teacher training methods have to be adapted, and in turn, STE teachers have to learn how to teach their students reading strategies, so they can successfully learn from STE texts. In order to achieve this goal, teacher training programs, first of all, have to equip future teachers with the awareness that every teacher is also a teacher of reading, and that a STE teacher is responsible for developing STE reading competence in his students. Secondly, research programs for STE teachers and lifelong learning courses have to equip their students/teachers with metacognitive STE reading skills, as well as with knowledge about the didactics of STE scaffolding strategies for reading both types of STE texts: for reading informative, explicatory, expository texts and for reading procedural texts, which describe engineering and technical processes. This is a huge shift in STE teacher training education, which is probably impossible to occur in a short span of time, because it requires, above all, changes in the prejudiced attitudes of teacher training staff, which often include a firmly rooted conviction that for a STE teacher the only important knowledge is scientific knowledge of the selected scientific field, while everything else that will eventually be needed in the process of students' knowledge acquisition, is someone else's responsibility.

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