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METACOGNITIVE MODEL FOR DEVELOPING SCIENCE, TECHNOLOGY AND ENGINEERING FUNCTIONAL LITERACY

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Abstract. *Science, technology and engineering functional literacy should be developed purposely in the school system – like any other competence, it does not develop spontaneously. For this purpose, a didactic model, the Metacognitive Model for Developing Science, Technology and Engineering Literacy (McM_T&E), was developed. Apart from acquiring knowledge and skills from the field of technology and engineering, the McM_T&E is equally focused on developing functional literacy in the field of technology and engineering, as well as in the field of science, through the development of students' metacognitive knowledge about reading strategies for reading STE explicatory texts and for reading manufacturing instructions. The McM_T&E was implemented in a Technology and Technique' (T&T) class, grade six, in Slovenia. Results show that focusing on science, technology and engineering literacy in Technology and Engineering classes by using the McM_T&E model increases the students' science, technology, and engineering functional literacy, which is a fundamental competence in the 21st century.*
Keywords: *functional literacy, metacognitive didactic model, science functional literacy, technology, engineering functional literacy.*

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Introduction

The term functional literacy does not reflect the essence of competence any more, since in today's complicated world each scientific field has created a specific language and a specific way of structuring texts, in order to present knowledge about the world and its nature. A consequence of this is that the school system has to develop specific literacies, including science, technology and engineering literacy in the frame of STEM literacy (Cencelj, Kordigel Aberšek, Aberšek & Flogie 2019).

Nowadays there is a general agreement that everyone needs to be STEM literate, but there is wide variation with respect to what that means. As 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, p.7). The question of STEM literacy can be observed from the general and from the particular point of view: firstly, recapping Tarnoff (2010), that tomorrow's workforce will require innovators, who will need to possess creativity and communication skills in order to develop products and services that will drive global economy. Alternatively, agreeing with Zollman (2012), who included the need to fulfil personal needs, as well as societal and economic needs, and who specifically stated STEM literacy needs beyond content and process. He pointed out that STEM literacy must also include the ability to communicate complex ideas to a wide variety of audiences.

An important part of STEM literacy is *technology and engineering (TE) literacy*. TE literacy in a narrow sense of the term is defined as *the capacity to use, understand, and evaluate technology as well as to understand technological principles and strategies needed to develop solutions and achieve goals* (NEAP, 2014). A broader understanding of TE literacy, analogically to STEM literacy, points out that a particularly important part of technological tools consists of information and communication technologies, and in this framework '*to communicate*' is understood as knowledge of these particular technologies and the skill of using them (NAEP, 2014). This is, without a doubt, a very im-

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portant competence – which must be (and is) developed as a part of digital literacy for the 21st century (Carretero, Vuorikari & Punie, 2017).

The term 'TE literacy' refers, apart from an ethical use of scientific and engineering knowledge, also to the knowledge about science, technology and engineering, and to the competence of understanding and using science/technology/engineering knowledge as the applicative part of science (NEAP, 2014). However, in an educational context, such a definition appears too narrow. It needs to be broadened by means of Zollmans' concept, which refers to the ability to communicate complex (technological and engineering) ideas to a wide variety of audiences (Zollman, 2012).

The term 'to communicate' needs to be looked more closely in the context of STEM and particularly TE literacy. Communication competence can be understood as competence in using a set of tools needed to participate intelligently and thoughtfully in the society, in one's professional life, and in the education system. However, 'to communicate' in the context of functional STEM and particularly TE literacy also refers to competence in accessing information, knowledge and skills within a problem-based curriculum. For this reason, problem-based curricula should also integrate functional literacy strategies, such as for instance the Reciprocal Teaching or the Internet Reciprocal Teaching methods, which systematically develop students' competence of asking questions, locating information, critically evaluating information, synthesizing information and communicating new knowledge (Leu, Coiro, Castek, Hartman, Henry & Reinking, 2015). All this is needed in order to develop a conceptual understanding of the content and the processes of problem-solving (Lefever-Davis & Persman, 2015).

TE functional literacy has much in common with STEM literacy (Cencelj et al. 2019) and general literacy, but it is characterized by some specific properties/attributes. This is a complicated relationship, which deserves a closer look and will be explored in the next paragraphs.

General Functional Literacy – Science, Technological and Engineering Functional Literacy

Functional literacy is a structured competence consisting of prior knowledge, inferential reasoning, metacognition and emotional variables related to effectiveness and motivation (Coiro&Dobler, 2007). The same structure is also typical of STE functional literacy, however, in the frame of each structural element required for understanding what was read in informational, explicatory and other texts typical of technology and engineering, we can observe significant differences from those described in general functional literacy.

Table 1
General functional literacy vs. science, technological and engineering functional literacy

	General functional literacy	STEM literacy
Prior knowledge	Code Grapheme level Morpheme level Semantic level Thematic knowledge Text knowledge	Code Grapheme level Morpheme level Semantic level Thematic knowledge Text knowledge
Inferential reasoning	Reasoning, based on verbal textual clues. Reasoning, based on structural textual clues. Reasoning on contextual clues.	Reasoning on the base of verbal and visual textual clues. Reasoning on the base of synchronic processing of verbal and visual textual clues. Inferential bridges (the use of STEM knowledge).
Metacognition	What influences the reading success? Knowing reading/studying (KWL, Pauko strategy, Reciprocal reading, etc.). Why is the chosen reading strategy the optimal choice for concrete reading goal?	What influences the reading process of STEM text? Knowing reading/studying strategies for STEM texts (informative, explicatory, instructional plan, etc.). Why is the chosen reading strategy the optimal choice for concrete reading goal?

(Adopted after Coiro&Dobler, 2007)

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Prior knowledge. Already in the last two decades of the previous millennium, research (Alexander, Kulikowich & Schulze, 1994; Means & Voss, 1985; Englert & Hiebert, 1984) proved that a high interdependence exists between prior knowledge and reading comprehension. This interdependence was proven to exist on all three levels of pre-knowledge: overlapping of the code, thematic pre-knowledge, and knowledge about text structure (Weaver & Kintsch, 1991; Coiro, Dobler, 2007). In the frame of TE functional literacy, the problem of pre-knowledge is even more urgent, since this pre-knowledge differs from the usual communication patterns used in everyday life and in spoken language by far more than the pre-knowledge required in general functional literacy.

Particularly important in reading a (S)TE text is the pre-knowledge of code. There are significant differences between general and science, technological and engineering texts on all levels of code: phonology, morphology, syntax, semantics and pragmatics (Kordigel Aberšek, Cencelj, Aberšek, Flogie, 2019; Cencelj et al., 2019). The same grapheme used in general literacy code can mean something different from what it means in an STE text. An exclamation mark (phoneme level) in general language stands as a sign for a type of emotion, an exclamation mark in engineering (and mathematics) text means *factorial*. On the morpheme level, OH in general language signifies an expression of wondering. In an STE text (in chemistry), it means alcohol. In addition, on the semantic level the equation t=s/v is not understandable at all. In general language, there should be a sentence such as *"you are going to reach your point of destination sooner, if you drive faster".*

Pre-knowledge at the semantic level of the text is essential in the process of *inferential reasoning.* Technical science and engineering thematic pre-knowledge make a key distinction between general and STE functional literacy: in a general functional reading situation, in order to create coherence, a reader needs general knowledge and general logical thinking for building inferential bridges (Kintsch, 1988). On the other hand, for inferential bridges in the process of creating coherence in a STE explicatory and explanatory text, the reader requires specific science, technology and engineering knowledge.

Another important difference in inferential reasoning between general functional literacy and science, engineering and technological literacy is *inferential reasoning between verbal and visual text*. For inferential reasoning between verbal and visual coded text a general visual literacy is sufficient (Greenfeld, 2009). On the other hand, (S)TE texts use specific visual codes, and text coherence can be established only through a *synchronized perception of both kinds of signals and creating inferential bridges between them* (Kordigel Aberšek et al., 2020). Texts from the field of science, engineering and technology use a greater quantity of non-verbal linguistic means (characters) than texts from other natural science disciplines. They use (like in mathematics) a significantly greater quantity of alphanumeric symbols, mostly arranged into formulas, equations, and a greater quantity of graphic representations, tables, charts, diagrams. They include non-standard pictorial representations/images extensively, and, of course, most importantly, technical documentation employs a special kind of visual language: blueprints, drawings, lists, schemas, graphical descriptions of manufacturing procedures, etc.

Observing *metacognition* in (S)TE literacy and in general literacy shows some differences. Very important in both of them is the awareness of what increases the success of the reading activity (Kordigel Aberšek, 2017). However, reading strategies in an (S)TE reading act are different from those in reading fiction and even in reading general non-fiction, because (S)TE texts have typical structures which are specific to them only.

Table 2
General literacy metacognition via STE literacy metacognition

Metacognition	General functional literacy	STE functional literacy
	What influences successful reading	What influences a reading process of a STE text
	Knowing reading/study strategies	Knowing reading/study strategies for STE texts (informative, explicatory, instruction plan …)
	Why is the chosen reading strategy the optimal choice for achieving my reading goal?	Why is the chosen reading strategy the optimal choice for my reading goal?

In the frame of STE literacy, two text types are of particular importance*: explicatory and explanatory texts,* and *manufacturing instructions*. Explicatory and explanatory texts have a text structure similar to narrative texts, but exhibit a specific inner logic structure, such as definition, description (or description of a procedure), cause – effect, problem-solving… (Fisher, Frey & Lapp, 2009).

https://doi.org/10.33225/jbse/20.19.220

The second type of text, *instructions for use* or *manufacturing instructions,* is a specific type of procedural text. *Instructions for use* and *manufacturing instructions* are, as regards the quantity of used non-verbal symbols and visual characters, quite similar to expository and explanatory texts from the field of engineering and technology. However, the two text types are distinguished by the role of the concept of time, and the perception of the concept of time in understanding the meaning of the text and achieving the (functional) purpose, for which the reading act was intended. For expository and explanatory texts from the field of engineering and technology, the temporal category is irrelevant for the understanding of the text (for achieving the purpose of the text). On the other hand, with instructions for use and manufacturing instructions (i.e., for describing a procedure or process), the understanding of time and the consecutiveness of chronological steps, is of vital importance.

For each of the text types a different reading strategy should be used (and learned). Consequently, metacognitive knowledge in the frame of STE literacy should include at least two reading strategies: an *explicatory/explanatory text reading strategy* and a *manufacturing instructions reading strategy*.

STE functional literacy is significantly different from general functional literacy. In today's world, competence in communicating about scientific, technological and engineering topics is too important to let it "simply emerge" from students' own interest in science and technology. In today's world, science, technology and engineering are so important that STE functional literacy should be developed in contemporary school curricula in order to meet the demands stated in the definition of engineering literacy provided by the International Society for Technology in Education (2000). According to this definition, 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.

The main objectives of this research were

- to develop a special teaching model for improving (S)TE functional literacy, the Metacognitive Model for Developing Technology and Engineering Literacy (McM_T&E). Apart from acquiring knowledge and skills from the field of technology and engineering, the McM_T&E is equally focused on developing functional literacy in the field of technology and engineering, as well as in the field of science, through the development of students' metacognitive knowledge about reading strategies for reading STE explicatory texts and for reading manufacturing instructions.
- To measure the effectiveness of McM_T&E on (S)TE functional literacy after implementing the model in Technology and Technique' (T&T) classes.
- To compare the level of (S)TE functional literacy between students who were taught using McM_T&E and those who were taught in a traditional way.

The following research questions were formed:

- How much will effective reading comprehension of *expository texts from the field of engineering and technology* improve after implementing McM_T&E*?*
- How much will effective reading comprehension of *manufacturing instructions* for a product improve after implementing McM_T&E?
- How much will the quality of a product made according to instructions improve after implementing McM_T&E?
- How much will the quality of a product made according to students' own idea improve after implementing McM_T&E?
- How much will the creativity of a solution made according to students' own idea improve after implementing McM_T&E?

Research Methodology

General Background

In the first step, a metacognitive model for science, technology and engineering literacy (McM_T&E) was developed as shown in Figure 1. The McM_T&E didactic model focuses on a systematic development of students' STE functional literacy, with the special aim of developing functional literacy in the field of technology and engi-

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neering (TE). To achieve this goal, two reading strategies were specially developed for implementation in the T&T class during learning activities: *a reading strategy for reading TE explicatory texts*, and *a reading strategy for reading manufacturing instructions*. Both strategies were designed based on positive research results with general functional literacy scaffolding strategies (Palincsar, Brown, 1984; Almasi, 2003; McNamara, Kendeou, 2011; Young, Hadaway (2016). These usually implement activities before, during and after the reading process. However, the activities in the TE explicatory text reading strategy and the TE manufacturing instructions reading strategy were designed according to the specifics of technology and engineering text structure (see Table 3). In addition, the McM_T&E includes didactic activities for digital literacy acquisition by encouraging students to use e-materials and apply the acquired information and knowledge in the use of different materials, semi-products, tools and machines for manufacturing their own products.

Figure 1
Metacognitive model for developing science, technology and engineering literacy

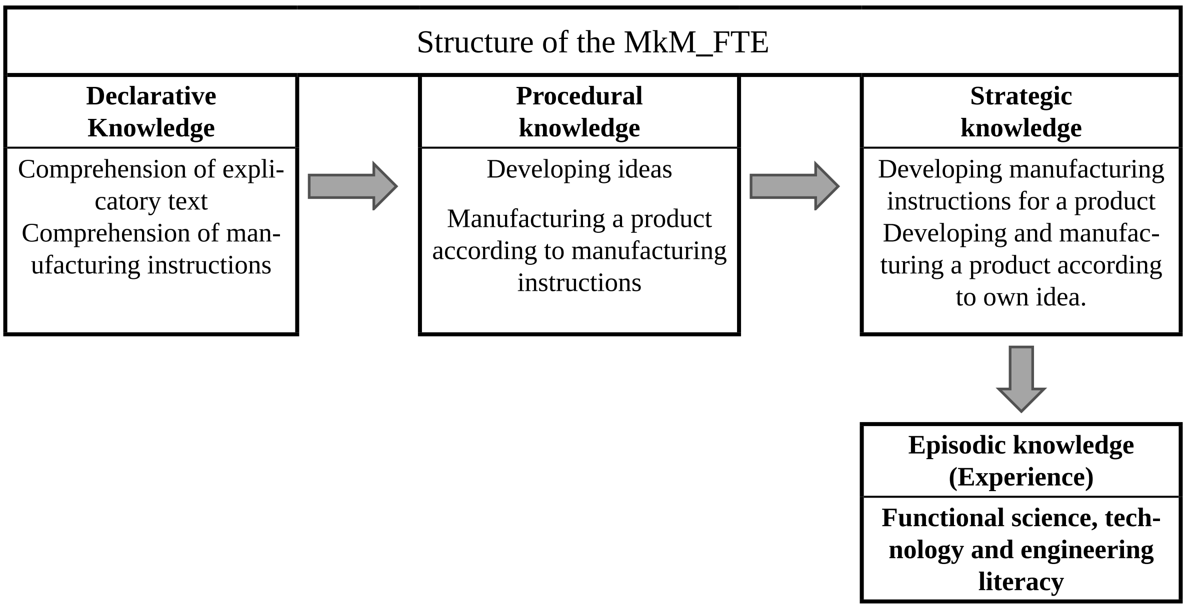

Table 3
STE reading strategies

Reading strategy for reading explicatory texts	Reading strategy for reading manufacturing instructions
1. Read the title. Flip through the text. Write down the questions that you expect the text to answer.	1. Read the title.
2. Mark the paragraphs for which you think contain answers to the questions asked.	2. Flip through the manufacturing instructions.
3. Read the text carefully and underline the unknown words. Write them down next to the text.	3. Read the manufacturing instructions.
4. Try to explain the meaning in simple words. You can consult a classmate; find an explanation online (dictionary, Wikipedia).	4. Prepare a large enough piece of paper, so that you can make a flow chart.
5. Re-read the text and underline essential ideas in important sentences.	5. Read carefully again and write down the individual steps onto the flow chart.
6. Divide a blank sheet of paper into 2:1 portions.	6. Look at your flow chart and prepare a list of materials you will need.
7. Write the underlined parts of the text in your own words on the left side of the sheet.	7. Review the flow chart and make a list of tools you will need.

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Reading strategy for reading explicatory texts	Reading strategy for reading manufacturing instructions
8. Look at the written text on the left. Write down the keywords on the right side of the sheet.	8. Think about what kind of working surface you will need.
9. Draw a mind map that summarizes the key information from the text.	9. Review your flow chart again and mark those stages of the process, for which you anticipate that something might go wrong.
10. Compare your answers with those of your classmate. Complete, correct answers.	10. Start manufacturing the product.

In the McM_T&E didactic model, a thematic unit takes place through four consecutive pedagogic phases:

- *acquisition of theoretical knowledge* needed for the manufacturing of a chosen product, and simultaneously learning/using a strategy for reading explicatory texts from the field of technology and engineering;
- *preparation of the process* of product manufacturing and simultaneously learning/using a reading strategy: manufacturing instructions, reading manufacturing instructions, collecting suggestions for improving the production process, thinking about performing particular (critical) steps in the manufacturing procedure;
- *manufacturing the product* (connecting theoretical knowledge and practical work);
- *evaluation and self-evaluation* (thinking critically about your work, correcting gaps in knowledge, summative assessment).

After developing the McM_T&E model, an evaluation followed. The basic research and evaluation method applied in the present study (Cencelj et al., 2019) was an experimental method of pedagogical research. The methods used belong to the framework of quantitative and qualitative research. In the preparation and adaptation of the metacognitive model (McM_T&E), action research was used to collect data on how the lessons and schoolwork were conducted. Basic information about the students was obtained by means of a questionnaire and a non-experimental method. Students' knowledge and the efficiency of their work were tested quantitatively, by measuring their reading understanding of an *expository text* from the field of engineering and technology and an example of *manufacturing instructions,* and qualitatively, by evaluating the quality of the manufactured product according to *manufacturing instructions* and according to the creativity of the solution (Cencelj et al., 2019).

Sample and Sampling

The McM_T&T didactic model was implemented in two classes of 'Technology and Technique' (T&T classes) in a Slovene school, as part of a thematic area called 'making products from paper materials'. The survey included 108 students, 54 from the classes where the McM_T&T was implemented, and 54 from two classes where teaching proceeded according to the traditional didactic paradigm. The sample was collected from all sixth and seventh grade classes at this school. With respect to gender, the sample consisted of 55 boys (51%) and 53 girls (49%) (Cencelj et al., 2019).

Firstly, a test was carried out to identify the existing situation – the ability of transferring general functional literacy, acquired in mother-tongue classes, to the level of functional literacy in the field of engineering and technology. Reading speed and text understanding were tested in two reading situations: reading an expository text from the field of engineering and technology, and reading manufacturing instructions from the field of engineering and technology (Cencelj et al., 2019).

The next step was the adoption of learning content about the materials needed in the working process, and the making of the product. Students were divided into two groups: the experimental group (EG) and the control group (CG). Students in the CG were taught using the traditional teaching method. Students in the EG were taught using the McM_T&E, which is based on process-oriented instruction, focuses on developing functional literacy in the field of engineering and technology, and uses formative monitoring of the students' progress.

In the final phase, after ten months of implementation of the McM_T&E, the reading comprehension of an expository text from the field of technology and engineering and of manufacturing instructions was re-tested. By comparing the obtained results, the students' progress in reading speed and in understanding of the read text,

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was measured. After reading an *expository text about the materials* used for the product and the *manufacturing instructions*, students in the TE class were asked to manufacture a gift bag. The first assignment was to make a gift bag according to the given manufacturing instructions and the second one was making a gift bag according to their own idea, to show creativity and innovation.

Instruments

In both examinations (both in the pre-test and at the end of the survey), the same text was used, and both groups were given the same criteria for evaluating work and the same content treatment, which in the end produced comparable results. In order to test the comprehension of an explicatory/explanatory text and manufacturing instructions for a product, questions on different difficulty levels were prepared. In order to test the ability to use the knowledge/information from the text, two criteria were formed: a criterion for evaluating a product manufactured according to instructions, and a criterion for evaluating a product manufactured according to own idea. To evaluate the students' products and their answers on the questionnaires, we created an expert evaluation group, consisting of two STE teachers, who taught in the control group (CG) and the experimental group (EG), a mother-tongue teacher, and an expert from the technology didactics field.

The measuring instrument contained three main parts:

1. student information,
2. test of the theoretical understanding of the text (speed of reading and reading comprehension test for explicatory/explanatory texts/manufacturing instructions for a product), and
3. test of the practical understanding of the text (manufacturing a product according to instructions/manufacturing a product according to own idea).

The text for testing the *effective speed of reading of an explicatory/explanatory text* contained 682 words and 10 photographs. The text included a description of the procedure for making a wheat starch paste (adhesive) and information about paper materials. The text containing the *description of the procedure for making a product* contained 568 words and 32 photographs showing the tools and materials needed for making the product and the individual phases of the procedure.

We evaluated the comprehension of the read technical text and manufacturing instructions by calculating the effective reading speed, taking into account the number of words read per minute and the percentage of correct answers:

$$\text{Effective reading speed} = \frac{no.words\ per\ minutes \cdot \%\ correct\ answers}{100}$$

Based on the calculated effective reading speed (the product of the number of words read per minute and the percentage of correct answers), we distinguished five types of readers: weak readers (effective reading speed 22 or less), poor (from 22 to 45), average (from 45 to 75) good (75 to 90), very good (more than 90).

Testing the practical understanding of manufacturing instructions contained two subcategories:

- manufacturing a product according to the instructions provided (comprehension during the preparation for manufacturing a product according to the instructions provided, and comprehension during manufacturing a product according to the instructions provided), and
- at a higher cognitive level, comprehension of the read manufacturing instructions for making a product according to your own idea (creating instructions for making a similar product according to your own idea, manufacturing a product according to your own idea, creativity in manufacturing a product of your own choice).

According to the total number of points achieved and the difficulty level, the expert evaluation group designed a five-level Likert scale (weak, poor, average, good and very good readers) in order to measure the practical understanding of the manufacturing instructions.

https://doi.org/10.33225/jbse/20.19.220

Data Analysis

The effectiveness of the McM_T&E and its impact on the level of STE functional literacy was assessed by taking into account the results achieved by means of all three instruments (effective reading speed of a technical text and manufacturing instructions, making a product according to the instruction provided, and making a product according to your own idea and creativity). The points scored in the effective text reading speed check (EHB) represent 25% of the total reading comprehension score. Manufacturing the product according to instructions and manufacturing the product according to your own idea (VNL) represents 60% of points, and creativity (UST) 15% of points:

$$\%\ of\ points = \left(\frac{EHB \cdot 0{,}25}{Total\ EHB} + \frac{VHL \cdot 0{,}60}{Total\ VHL} + \frac{UST \cdot 0{,}15}{Total\ UST}\right) \cdot 100$$

Given the total effective reading speed, product manufacturing and creativity, the expert evaluation team developed a categorization of readers according to the degree of their functional literacy in the field of technology and engineering.

The group of *weak readers* (students who very poorly correlate the read manufacturing instructions with the practical part of making a product) includes students who scored up to 45% points in the design and production of the product. Students who scored from 45% to 60% of points were classified as *poor readers*. Students who scored from 60% to 75% of points were classified as *average readers*, and students who scored from 75% to 90% of possible points were classified as *good readers* (these are students who can be said to be functionally technically literate). *Very good STE readers* were students who scored 90% of points or more.

Research Results

Analysis of the impact of increased functional literacy in the field of technology and engineering after using the MKM_FPT model on product quality and product creativity

In analysing the performance of the MKM_FPT model, the differences between the EG and the CG are presented:

- in effective reading speed,
- in reading comprehension of manufacturing instructions and of making a product according to the instruction provided,
- in designing instructions for a product according to one's own idea, and differences in the quality of making a product according to one's own idea,
- in creativity.

Analysis of Effective Reading Speed

As part of the analysis of effective reading speed before and after the research, Table 4 shows differences in the effective reading speed of a technical text and manufacturing instructions in the pre-test and post-test, with respect to the EG and the CG.

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Table 4
Wilcoxon test for comparing the effective reading speed according to the pre-test and post-test

Effective reading speed		AMD EFHz - EFHk (N in %)						
Group		AMD	EFHz < EFHk	EFHz > EFHk	EFHz = EFHk	Mean rank	*Z*	*p*
EG	TT	-17.83	83.33	16.67	0	28.96 20.22	-4.826	< .0001
	MI	-23.02	96.30	3.7	0	28.29 7.00	-6.273	< .0001
CG	TT	-0.30	44.44	55.56	0	30.42 25.17	-0.108	0,914
	MI	-13.14	72.22	27.78	0	30.54 19.60	-3.862	< .0001

TT – technical text; MI – manufacturing instructions; AMD – arithmetic mean difference

Types of readers according to effective reading speed of an explicatory text (technical text) in the pre-test and post-test are presented in Figure 2.

Figure 2
Reader type according to effective reading speed in the pre-test and post-test, for reading a technical text

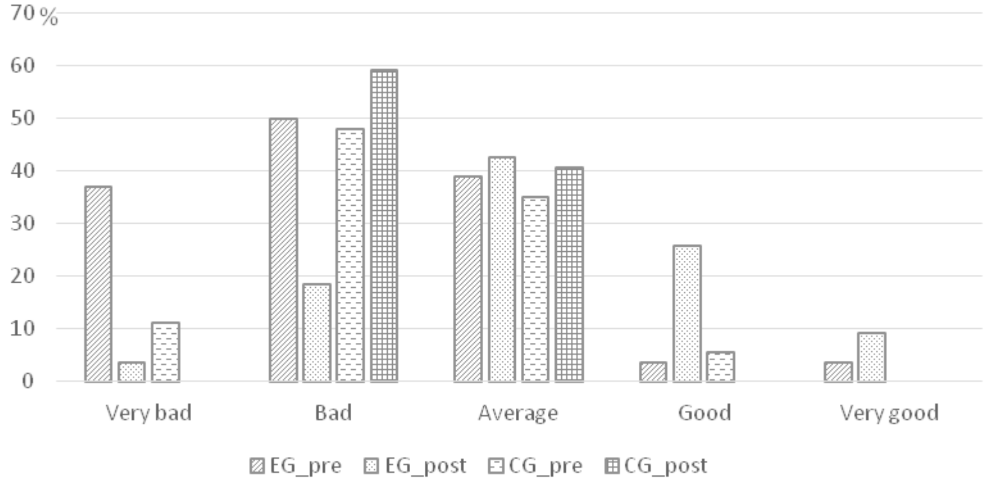

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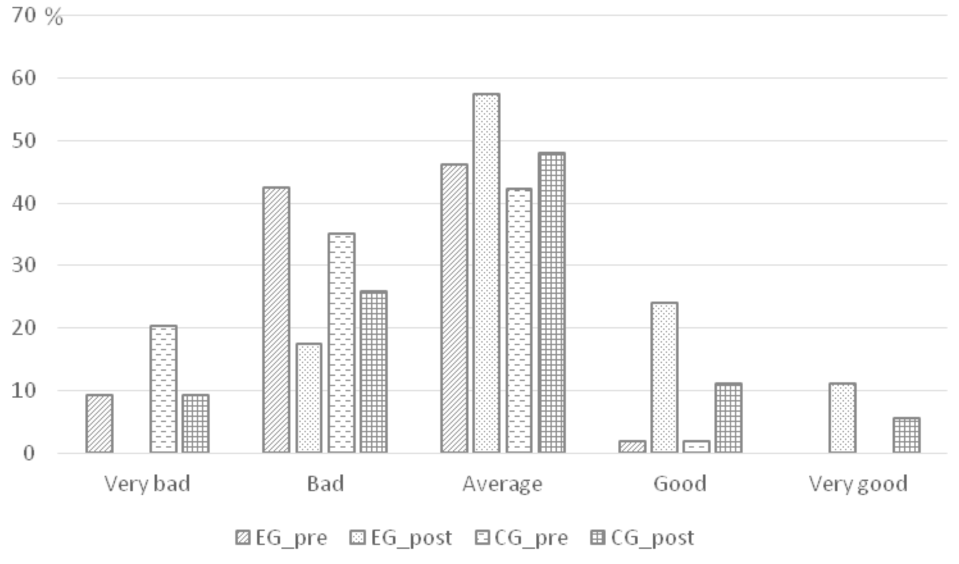
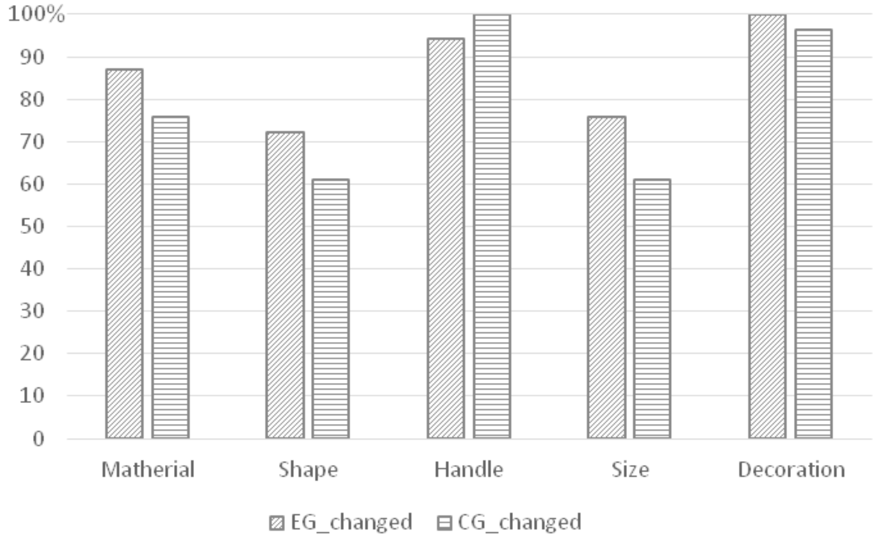
Figure 3
Reader type according to effective reading speed in the pre-test and post-test, for reading manufacturing instructions



Designing Instructions for a Product According to One's Own Idea, and Differences in the Quality of Making a Product According to One's Own Idea

Figure 4
The difference between the changes made, with respect to manufacturing a product according to one's own idea and manufacturing a product according to the instructions provided, in the EG and CG.



Values of the Mann-Whitney test for comparing the EG and the CG in terms of creativity are presented in Table 5.

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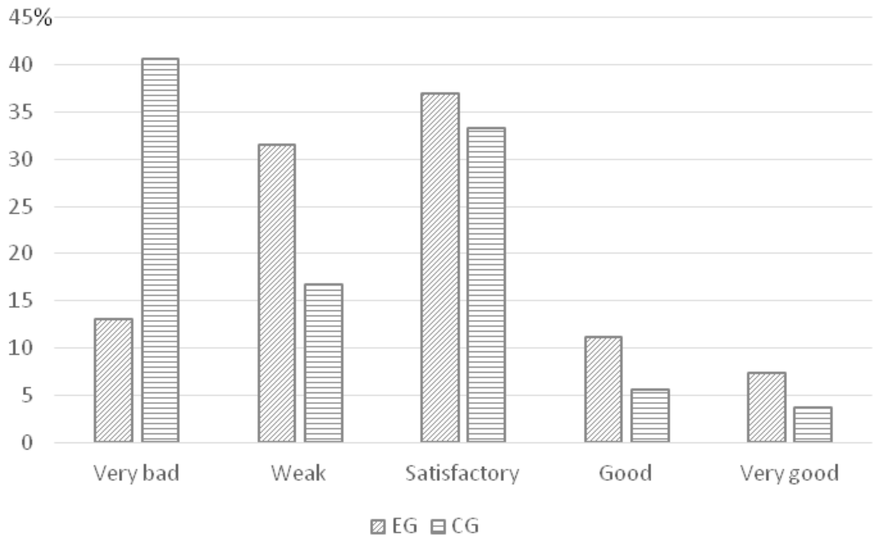
Table 5
Values of the Mann-Whitney for comparing the EG and the CG from the perspective of creativity

		Material	Shape	Size	Handle	Decoration	Overall
Mann-Whitney		1318.00	1443.00	1176.50	1344.00	898.00	1095.50
Z		-0.902	-0.097	-1.791	-0.758	-4.161	-2.233
Asymp. Sig (*p*) (2-tailed)		0.367	.923	.073	.448	< .0001	.026
Mean range	*EG*	57.09	54.78	59.71	56.61	65.87	61.21
	CG	51.91	54.22	49.29	52.39	44.13	47.79

Creativity

Figure 5
Creativity with respect to manufacturing a product according to one's own idea in the EG and CG



Discussion

The results concerning technology and engineering functional literacy, achieved after implementing the McM_T&E didactic model, are particularly important in the light of Japanese Ministry of Education's committee, which recommends adjusting the education system to meet the needs and values of Society 5.0, from primary school to the university level (Kordigel Aberšek & Aberšek, 2020). The committee reached an overall conclusion: in order to prepare students for the rapid technological change, *the key is to focus on human strengths* – skills such as communication, leadership and endurance, as well as curiosity, comprehension and reading skills. In order to make this happen, students' basic skills should be perfected by the time they reach the fifth, sixth or seventh grade.

Among basic skills, the skill of reading is a fundamental one. Basic skills are the foundation for everything. Barriers between subjects and disciplines need to be removed in order for the next generation to be prepared for the super-smart future. Subjects such as math, data science, and programming are among the basic requirements of future educational systems, but also subjects such as philosophy and language. The McM_T&E didactic model is based on such didactic philosophy: it combines the reading curriculum, which is traditionally implemented in mother-tongue classes, and the technology and engineering curriculum, which is implemented in STE classes. A

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basic requirement of the McM_T&E didactic model is collaboration between the mother-tongue teacher and the technology and science teacher. Such collaboration provides an opportunity for technology and science teachers to adopt reading metacognition knowledge from mother-tongue teachers (who focus on general functional literacy acquisition in their classes), and to transfer this knowledge to the reading situation in the process of communicating knowledge (i. e., reading and writing) in the field of science and engineering. Such teamwork allows the (S)TE teacher to develop reading/scaffolding strategies, adjusted for reading and comprehending texts which students use in the frame of science and technology classes. Integrating the reading curriculum with the science, technology and engineering curriculum, as in the McM_T&T didactic model, is a very valuable way of developing (S)TE functional literacy. The McM_T&T didactic model develops students' subject-specific vocabulary and the pre-knowledge needed for the comprehension of science, technology and engineering texts. It systematically introduces the specific code used by technology and engineering texts.

Finally, and perhaps most importantly, the McM_T&E didactic model provides a suitable amount of science, technology and engineering knowledge for building inferential bridges between information gaps in the text with the aim of understanding the text – not only on the lowest cognitive level, but also on the level of critical thinking (Cencelj et al., 2019). Such connectedness of knowledge and critical thinking is particularly important from the perspective of researchers working in the area of critical thinking, which agree on the important role of background knowledge for critical thinking and see background knowledge as essential if students are to demonstrate their critical thinking skills (Case, 2005; Willingham, 2007). To "think critically, students need something to think critically about" (McPeck, 1990, p.11).

Results of the research presented in this paper showed an important growth also in students' creativity: 87% of students in the experimental group creatively changed the material for their product after being taught according to the McM_T&E didactic model, 72.2% changed the shape, 75.9% changed the size, and all of them (100%) creatively changed the product decoration. In comparison, results of the control group showed a lower level of creativity: only 75.9% creatively changed the material, 61.1% changed the shape and size, and 96.3% changed the decoration. Creativity, as developed through the McM_T&T didactic approach, should undoubtedly assist students in achieving 'competence in fast and effective problem-solving', which will be needed in the super-smart Society 5.0 (Kordigel Aberšek & Aberšerk, 2020).

Basic reading competence and general functional literacy represent an important gateway to learning successes in the whole curriculum, and STE functional literacy is a key competence in knowledge acquisition in STE curricula. Based on these premises, we can conclude that focusing on TE functional literacy competence acquisition in the McM_T&E didactic model is a solution for the concerning differences in science knowledge between students. This is even more important if we consider the fact that children who fall behind in reading achievements are unlikely to catch up later (Leu et al., 2014). The level of technological knowledge and competences of such children are going to stay the same and are unlikely to grow.

There is no doubt that science, technology and engineering functional literacy, which is systematically developed while using the McM_M&E didactic model, is extremely important in the context of preparing children for adult life in the world of *Society 5.0,* a *super-smart society* (Kordigel Aberšek & Aberšerk, 2020). From the presented research we can conclude that the metacognitive model McM_T&E is appropriate and that it delivers favourable results in all three research areas, i.e., in *effective reading* of explicatory and explanatory texts, in *designing instructions for a product,* and in *creativity.*

Conclusions

In the 21st century, globalized world science and technology are going to change everyone's life in shorter and shorter intervals. The quickly developing engineering and technology knowledge will make the knowledge acquired in schools useless very soon after one enters professional life. Consequently, it is essential for global economy to equip students with functional literacy in science and related fields, so that in the process of lifelong learning, they will be able to follow such changes, particularly those that arise from the development of technology.

The metacognitive model for developing science, technology and engineering literacy (McM_T&E) seems to be, according to the positive results of the presented research, a suitable solution for the problem of low achievements in reading explicatory and explanatory texts from the field of science, technology and engineering in todays' young generation. In the future, today's school generation will be constantly confronted with new technology and engineering knowledge, more often than any generation before them.

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