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Creative Thinking and its Role in Industry 5.0 Era

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Abstract. The present study characterizes the emerging era of Industry 5.0 (Gabriel, 2021) and highlights the importance of creative thinking for this future. Industry 5.0 deals with technological development not only through technical and economic evaluation, but also with the help of innovations. It moves the industry's goals from optimizing production processes to sustainable, socially beneficial and, above all, human-centered production. The technological aspect should be balanced by strengthening human talents and investing in education. The article presents the results of the OECD's *PISA 2022* (OECD, 2024) global survey, which aimed, among other things, to determine the level of creative thinking among 15-year-old respondents from around the world, i.e., the future productive generation. A total of approximately 690,000 pupils, representing around 29 million pupils in 81 countries and economic regions around the world, participated in *PISA 2022*. The study also shows the teaching strategies that led to achieving the best results in the *PISA 2022* tests for pupils from Singapore. In the Czech Republic, 430 schools and nearly 11,000 pupils participated in the survey (PISA 2022 National Report Creative Thinking, 2023). The results of this investigation were contrasted with the results of the Urban Figurative Test of Creative Thinking for primary school pupils in the Czech Republic. The results of this test, however, showed that fifth-grade pupils achieved the highest scores, which has also been proven by other research (Chalupa, 2012; Novotný, 2012). The study also points out social development and its influence on education, where creative thinking will be very important. Based on the results of various studies, this study also presents the competencies necessary in the Industry 5.0 era (Earp, 2024).
Keywords: Industry 5.0, creative thinking, testing creativity, development of creativity.

Kūrybinis mąstymas ir jo vaidmuo Pramonės 5.0 eroje

Santrauka. Tyrime apibūdinama nauja Pramonės 5.0 era (Gabriel, 2021) ir parodoma kūrybinio mąstymo svarba. Pramonė 5.0 technologijų plėtrą vertina ne tik techniniu ir ekonominiu požiūriu – pasitelkdama inovacijas, ši paradigma perkelia pramonės tikslus nuo gamybos procesų optimizavimo prie tvaraus, socialiai naudingo ir, svarbiausia, į žmogų orientuoto gamybos modelio. Technologinė Pramonės 5.0 dimensija turėtų būti subalansuota stiprinant žmogiškąjį potencialą ir investuojant į švietimą. Straipsnyje pateikiami OECD PISA 2022 (OECD, 2024) tarptautinio tyrimo rezultatai. Tyrimo tikslas, be kita ko, buvo nustatyti būsimos produktyvaus darbo kartos – 15 metų amžiaus

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respondentų iš viso pasaulio kūrybinio mąstymo lygį. PISA 2022 tyrime dalyvavo apie 690 000 mokinių, atstovaujančių apie 29 milijonams viso pasaulio mokinių iš 81 šalies ir ekonominio regiono. Tyrimas taip pat atskleidė mokymo strategijas, kurios leido Singapūro moksleiviams pasiekti geriausių PISA 2022 testų rezultatų. Čekijoje tyrime dalyvavo 430 mokyklų ir beveik 11 000 moksleivių (PISA 2022 nacionalinė ataskaita „Kūrybinis mąstymas“, 2023). Šio tyrimo rezultatai buvo palyginti su Čekijos pradinių mokyklų mokinių Urbanistinių figūrų kūrybinio mąstymo testo (angl. *The Urban Figurative Test of Creative Thinking*) rezultatais. Šio testo rezultatai atskleidė, kad aukščiausius įvertinimus gavo penktokai, tai patvirtina ir kiti tyrimai (Chalupa, 2012; Novotný, 2012). Tyrime taip pat atkreipiamas dėmesys į socialinę raidą ir jos įtaką švietimui, kur kūrybinis mąstymas bus labai svarbus. Remiantis įvairių tyrimų rezultatais, straipsnyje taip pat pateikiamos Pramonės 5.0 erai būtinos kompetencijos (Earp, 2024).
Raktažodžiai: Pramonės 5.0 era, kūrybinis mąstymas, kūrybiškumo testavimas, kūrybiškumo ugdymas

Introduction

Creativity, understood as self-actualization, belongs to the basic human needs such as physiological needs, the need for love, recognition and belonging. Therefore, creativity is a distinctive feature of every individual, but in different forms, areas and levels (Honzíková, 2015).

Creative thinking is the ability to generate new and original ideas and solutions (Lokšová & Lokša, 2001). It is important because it promotes innovation, which is crucial for economic growth and competitiveness. In the work environment, creative thinking allows for identifying and solving problems in non-traditional ways, which can lead to more efficient processes and products. Creative individuals often bring new perspectives that can improve team dynamics and collaboration (Torrance, 1969). In addition, creative thinking increases personal satisfaction and motivation because it provides a space for expression and self-actualization. In an era of rapid technological change and globalization, the ability to adapt, respond creatively, and innovate is crucial to the long-term success of not only the individual but the entire society. Overall, creative thinking is essential for staying relevant and growing in a dynamic world (Earp, 2024; Croft, 2024). In the upcoming era of Industry 5.0, creative thinking is directly necessary for not only people to collaborate but also to work with new technologies to create more efficient and sustainable production processes (Müller, 2020).

According to the *PISA 2022* National Report (OECD, 2024), creative thinking is considered a key competence for the 21st century, helping young people better adapt to a rapidly changing society, discover and fulfill their potential, and solve problems in everyday life more effectively. Fifteen-year-olds leave the middle school and begin to prepare for further studies or a role in the work process in the era of Industry 5.0. Therefore, the international PISA 2022 survey, organized by the OECD, focused on assessing the creative thinking of fifteen-year-old students. This survey was included in the PISA program for the first time, and its aim was to assess the ability of students to generate original ideas and solutions. The results of this research should contribute to the innovation of primary school education systems to prepare graduates for the future in the Industry 5.0 era. The aim of these innovations is to create an inspiring learning environment that motivates students to discover new things and develop their creativity. Actively engaging pupils in learning and encouraging their motivation is key to developing creative thinking. It

is essential that pupils should have the opportunity to come up with their own ideas and solutions in a supportive and inspiring environment. The implementation of these measures should lead to pupils being better prepared to face the challenges of the 21st century and to succeed in society.

The future in the form of Industry 5.0 era

The *Industrial Revolution*, dubbed *Industry 4.0*, has mainly focused on automation and digitalization through the currently commonly used technologies such as the *Internet of Things* (IoT), *Artificial Intelligence* (AI) and robotics (Matt, Modrák, and Zsifkovitz, 2020, 2021). The Industry 5.0 era emphasizes the synergy between people and advanced technologies to create smart, connected and sustainable manufacturing processes. "Industry 5.0 focuses on enhancing human capabilities through technology. It emphasizes the collaborative relationship between humans and robots, often referred to as cobots (collaborative robots). Cobots are designed to work with and assist humans rather than replace them. This collaboration enables a combination of human intuition and machine efficiency, leading to more innovative and customized manufacturing solutions" (Croft, 2024).

This era empowers people, emphasizes sustainability and ecology, and increases the resilience of manufacturing systems to be able to respond quickly to incoming changes.

If we were to define the core elements of Industry 5.0 era (Berg, 2022), we would mention the following:

- *Human-Centric Approach:*
  Human Creativity and Technology. Industry 5.0 integrates human creativity and decision-making with the powerful capabilities of machines and technology. It aims to ensure that technology supports human skills and is not just a substitute for them.
- *Personalization and customization:*
  Modulation, simulation, artificial intelligence, machine learning systems, and more accurate tools like sensors, actuators, and 3D scanners are used to understand customer preferences and help maximize prototyping to help realize customer requirements at a minimal cost. By combining the human touch with technological precision, Industry 5.0 enables personalized manufacturing to meet specific customer needs.
- *Sustainable and Resilient Production*:
  Sustainability. A focus on environmentally friendly and sustainable production processes is a key element. Industry 5.0 seeks to minimize the environmental impact of industrial production and promotes a circular economy.
  Resilience. Creation of resilient production systems, data collection, automated risk analysis and enhanced security, which will allow to change quickly, and to adapt to new conditions, is another important component.
- *Technology integration*:
  Collaborative robotics (cobots). Industry 5.0 uses collaborative robots that work directly alongside humans, increasing their efficiency and safety. By working with hu-

mans, cobots can provide assistance and improve production processes and people's general lives, thus emphasizing the importance of humans in the robotic technology.

Artificial intelligence and machine learning. AI and machine learning are being integrated into processes to support decision-making and find the optimal balance between productivity and efficiency of production.

Ivanov (2022) sees Industry 5.0 as a human-centered approach through three main pillars:

- *Resilience;*
- *Sustainability;*
- *Human centricity.*

Industry 5.0 intends to capture the value of innovative digital technologies and their human-machine interactions.

> Emran and Shafari (2022) they state in their work that: "Industry 5.0 refers to the collaboration of advanced technologies, such as robotics and intelligent solutions, with humans to improve efficiency and performance. In education, Industry 5.0 refers to the collaboration between these technologies and pedagogy and students to increase the effectiveness and efficiency of teaching and learning."

It follows from the above that, in the era of Industry 5.0, not only knowledge and skills but also creative approaches based on creative thinking will be important because this is about improving cooperative interactions between humans and machines.

For more detailed information, one can explore sources like the European Commission's report on Industry 5.0 (Research and Innovation) as well as other comprehensive guides on the topic (Clarify | Explore your industrial data) (Joining Innovation with Expertise).

The level of creative thinking in the upcoming productive generation

In addition to mathematical literacy, an international survey was conducted in 2022 to determine the level of creative thinking internationally. The results of this international investigation may have implications for changes in educational processes and the direction of modern conceptions of pedagogy.

There are many definitions of creativity and creative thinking, and their definition is influenced by the author's focus.

> "In the PISA 2022 project, creative thinking is defined as the ability to actively generate, evaluate and refine designs that can lead to original and effective solutions, to the creation of new knowledge and to compelling expressions of imagination" (Boudová, Tomášek, and Halbová, 2024).

This definition is based on a proposal from the Creative Thinking Strategic Advisory Expert Group. Interdisciplinary experts also participated in its formulation and created this definition based on the study of books on creative thinking. For clarification, the definition suggested by Kaufman and Beghetto (2009) is also used; they state that creativity

as a cognitive process which can be distinguished as big-K creativity (big-C creativity) and little-K creativity (little-C creativity). Big-K creativity is associated with intellectual or technological breakthroughs and artistic or literary masterpieces that require expertise in the relevant field. Creativity with the lowercase K is understood as the so-called creativity in everyday life. Creative thinking is seen as one of the key competencies for the 21st century, which needs to be developed in young people for several reasons: it helps to better adapt to changes in a rapidly changing society, allows students to discover and fulfill their potential, and supports learning and problem-solving in everyday life.

The *Programme for International Student Assessment* (PISA) focuses on assessing 15-year-olds, as this is the age at which most students in OECD countries complete compulsory schooling. This provides a common basis for international comparisons of education systems, as all students have completed a similar amount of formal education. Assessing 15-year-olds allows us to assess how well students are prepared for further education, their entry into the labour market, and active participation in society. This approach ensures relevant and comparable data across countries and cultures (PISA National Report).

Respondents

A total of approximately 690,000 pupils, representing around 29 million pupils in 81 countries and economic regions around the world, participated in the PISA 2022 international survey. A total of 64 countries and economic regions participated in the PISA 2022 international survey testing the innovative domain of creative thinking.

The research subjects were 15-year-olds. Approximately one in five pupils in each country took the 60-minute test. In the Czech Republic, a total of 2,635 pupils from 412 schools participated in the Creative Thinking test, with a maximum of 14 pupils per school, depending on the size of the school (PISA 2022 National Report Creative Thinking, 2023; Boudová et al., 2024).

Research methods

The testing was carried out by means of test-taking tasks. The students completed a two-hour cognitive test that included open-ended questions. These questions required students to create their own answers, which provided space for the students' creativity. The answers were not scored simply as right or wrong; they were assessed on the ability to think outside the box and come up with original solutions. The test domains were focused on generating creative designs, which meant developing one design in an open-ended scenario to be as original as possible, judging and improving the designs, where the respondents were asked to improve the originality of the submitted design. However, the research methodology has also been criticised in many of the participating countries. Some experts pointed out that some test items were ambiguous or misleading, which could affect the accuracy of the measurement of pupils' skills, or that the items focused on a limited number of subjects. Some countries, such as India, criticised the prioritisation of certain cultural or educational systems (EDUin).

The tests were divided into four areas (OECD, 2024):

Written Expression, Graphic Expression, Social Problem Solving, and Scientific Problem Solving.

Written Speech

Written expression is one of the most commonly used means of expressing creative thinking in and out of school. It requires logical consistency so that the reader understands and believes the idea.

Graphic expression

In the area of graphic expression, students experiment and try to express their ideas by using a variety of tools and resources. Individual test tasks required the use of a digital drawing tool so that a design could be created according to a given scenario.

Solving a social problem

The tasks focused on generating new ideas, and not on applying learned knowledge. The originality of the idea was assessed, as well as the creative thinking process in a scientific context. The areas of assessment of creative thinking were divided into problem-solving and creative expression. Two areas were included in problem-solving: social problem-solving and scientific problem-solving. Creative expression included written expression and graphic expression (OECD, 2024; Boudová et al., 2024).

A general indicator of the ability to think creatively is the number of ideas one is able to generate. This ability is called 'ideational fluency'. Creative thinking is characterized by the diversity of ideas, which can be called ideational flexibility (Amabile, 1983).

The creative proposal generation aspect of the PISA test focuses on students' abilities to find appropriate and original proposals in a variety of domains (e.g., an original story theme, an imaginative way of communicating a proposal in the graphic form, an original solution to a social or scientific problem). In other words, this aspect requires students to come up with suggestions for solving the task at hand that few would think of (OECD, 2024).

In the area of assessment, the PISA aspect of the test was concerned with assessing and refining ideas, that is, finding an original way to improve the proposal presented. These tasks may require certain cognitive skills, subject matter expertise, and experience in many different creative fields.

Excerpted from the Creative Thinking Test (OECD, 2024; Boudová et al. 2024):

Task assignment

You play a game where you have to roll dice and then connect the pictures that appear face up. These pictures are the inspiration for your story. You use only two dice as a warm-up. Write 2 different stories that relate to the pictures on the right. These two stories should be as different from each other as possible. Your work should take no longer than 7 minutes, and you should not use more than 80 words.

More at https://www.oecd.org/pisa/publications/PISA-2021-Creative-Thinking-Framework.pdf

Interpretation of results and discussion

Students' test scores were converted to a single final scale ranging from 0 to 60, where the highest value corresponds to the sum of the maximum possible scores for all test questions. The average results for all participating countries are shown in Table 1.1. The best-performing countries were Singapore, which also achieved the highest results in mathematics, reading and science literacy (see PISA National Report 2022), followed by students from the Republic of Korea, Canada, and Australia. Czech pupils achieved an average score of 33, which is the same as the average of the participating OECD countries, and their average score was significantly better than the average score of the participating EU countries. Pupils from twelve countries performed statistically significantly better than Czech pupils. Pupils from seven other countries had results comparable to those of Czech pupils, while at the same time, there are countries with results comparable to the OECD average.

Countries are ranked in descending order of the average country score (OECD, 2024).

Table 1. *Creative Thinking Test Results 2022, OECD 2024*

Country	Average result	Difference to the Czech Republic
Singapore	41,0	▲
Republic of Korea	38,1	▲
Canada	37,9	▲
Australia	37,3	▲
New Zealand	36,4	▲
Estonia	35,9	▲
Finland	35,8	▲
Denmark	35,5	▲
Latvia	35,1	▲
Belgium	34,9	▲
Poland	34,4	▲
Portugal	33,9	▲
Lithuania	32,9	○
Spain	32,8	○
OECD average	32,7	○
Czech Republic	**32,6**	
Taiwan	32,6	○
Germany	32,5	○
France	32,4	○
Netherlands	32,4	○
Israel	32,3	○
Macao (China)	31,6	▼
Hong Kong (China)	31,6	▼
Italy	31,4	▼
EU average	31,4	▼
Malta	31,3	▼
Hungary	30,9	▼
Chile	30,7	▼
Croatia	30,5	▼
Island	30,5	▼
Slovenia	30,0	▼
Slovakia	29,2	▼
Mexico	29,0	▼
Serbia	28,7	▼
Uruguay	28,6	▼
United Arab Emirates	28,4	▼
Qatar	27,7	▼
Costa Rica	27,5	▼
Greece	27,0	▼
Ukraine (18 regions out of 27)	26,9	▼
Romania	26,2	▼
Colombia	25,6	▼
Jamaica	25,5	▼
Malaysia	25,1	▼
Mongolia	24,9	▼
Moldova	23,9	▼
Kazakhstan	23,8	▼
Brunei	23,7	▼
Cyprus	23,7	▼
Peru	23,5	▼
Brazil	23,3	▼
Saudi Arabia	23,3	▼
Panama	23,2	▼
Salvador	23,0	▼
Baku (Azerbaijan)	22,8	▼
Thailand	20,9	▼
Bulgaria	20,7	▼
Jordan	20,2	▼
Northern Macedonia	19,1	▼
Indonesia	19,0	▼
Palestine	18,5	▼
Dominican Republic	15,5	▼
Morocco	15,5	▼
Uzbekistan	14,5	▼
Philippines	14,2	▼
Albania	13,1	▼

▲ It is statistically significantly above the OECD average;
○ Not statistically significantly different from the OECD average;
▼ Statistically below the OECD average.

In the PISA 2022 assessment of creative thinking, students from Singapore achieved the highest scores, followed by students from South Korea and Canada. The assessment measured the ability to generate, evaluate, and improve creative ideas across four domains: written expression, visual expression, social problem-solving, and scientific problem-solving. Singaporean students excelled despite many of them not perceiving themselves as particularly creative (OECD, 2024; Earp, 2024).

Other high-performing countries included Australia, New Zealand, Estonia, and Finland. The results highlighted significant disparities between the top-performing and lower-performing countries, with countries like Singapore, Korea, and Canada leading the way in fostering creative thinking among their students (OECD, 2024).

The top-performing students in the PISA 2022 creative thinking test were guided in specific ways in school to foster their creativity. Here are some of the key strategies and approaches used in schools that led to these successes (CNA, 2024):

1. *Encouraging and rewarding creativity*
   - Teachers' open approach. In the best-performing schools, teachers actively encouraged creativity by rewarding original ideas and encouraging students to come up with their own solutions. 60–70% of students in the OECD reported that their teachers valued their creativity and encouraged them to think outside the box (OECD, 2024).
2. *Engaging in creative activities*
   - Regular participation in creative activities. Students regularly participated in activities such as art, drama, creative writing or programming. These activities were integrated into their weekly schedule and proved to be an effective means of developing creative thinking (Earp, 2024).
3. *Teaching methods focused on creativity*
   - Project-based learning and open-ended assignments. Students were exposed to tasks that did not have one correct solution and were encouraged to think in original and innovative ways. These tasks included, for example, coming up with a story for a comic strip or different approaches to a school awareness campaign (OECD, 2024).
4. *Promoting growth mindsets and positive attitudes*
   - Promoting a growth mindset. Teachers encouraged students to believe that their creativity can evolve and improve. Students who had positive attitudes towards creativity and believed they could develop it performed better on tests of creative thinking (OECD, 2024).
5. *Technological and material facilities*
   - Availability of modern tools and resources. Schools provided access to a variety of technological tools and resources that enabled experimentation and creation. This included digital technologies that supported visual and scientific expression (CNA, 2024).
6. *Social and emotional support*
   - A friendly and supportive environment. Students worked in an environment that encouraged collaboration, openness, and respect for diverse ideas. This en-

vironment promoted idea sharing and teamwork, which is key to developing creative thinking skills (CNA, 2024).

These strategies and approaches in the school environment led to students developing their creative thinking skills and achieving high scores on the PISA 2022 test. These methods show that creativity can be learned, and that its development requires systematic support and the right conditions.

Czech pupils were significantly more successful in solving tasks where they had to provide creative ideas and performed worse in assessing and refining ideas.

Czech pupils were most successful in coming up with diverse, novel and 'different' ideas with elements of originality, surprise, novelty, and unusualness. Thus, they were able to break away from established patterns or models to a considerable extent, thus demonstrating to some extent the ability to think 'out of the box', not to be afraid, and not to go only the way of the stereotype (Boudová et al., 2024). At the same time, however, they were able to meet the condition of relevance, i.e., to bring ideas that are appropriate, suitable and beneficial within the context of the situation or task. In contrast, they were significantly less successful in the process of evaluating and refining suggestions or ideas in order to achieve a better solution or outcome. In the context of the PISA test, this was an assessment of the potential of the proposal being put forward to solve a given problem and how feasible it was. They evaluated its merits and suggested modifications or innovations to improve it. The assessment of the initial proposal itself entails a requirement to engage the pupil's critical thinking and analysis. The lower success rate of Czech pupils in assessing and improving designs encourages the promotion and dedication of sufficient space in teaching for critical assessment and thinking across different subjects (Boudová et al., 2024).

Testing creative thinking in Czech Republic

Regarding the results in the graphical expression of creative thinking, we tested elementary school students by using the Urban Figurative Test of Creative Thinking. The results were surprising.

As the basic research question, we set the hypothesis:

Does the level of creative ability increase during elementary school?

Research methods

Testing by using Urban's Figural Test of Creative Thinking (Urban, 2003). We first introduce the test.

Urban's Test of Creative Abilities – TSD–Z (CREATIVITY TEST)

Figural test of creative thinking – TSD–Z is actually a screening tool to provide a view of the creative potential of individuals. It is used as a tool to discover high creativity abilities on the one hand, whereas, on the other hand, it highlights underdeveloped capabilities. There are some advantages in the test, e.g., its simple administration and evaluation,

a large scope of research, and, not least, low demand on economics. The possibility of using the test for various age groups also counts among the advantages. The test consists of a sheet for A type and a sheet for B type. The sheet contains figural fragments (a semi-circle, a dot, a wave, a right angle, a dashed line, a small horizontal 'u' out of the frame), and the task for a respondent is to complete the drawings. The result is evaluated based on 14 criteria. When using the presented elements, points are given for every use of 6 fragments which the evaluation considers. These include thematic connections, new elements, design, unconventional use of individual elements, abstract elements, complexity of the picture, use of perspective, and, for example, humorous representations (Uban et al., 2003). This test is, therefore, similar in many ways to the PISA 2022 test, but its paper form may be unattractive to some young people, which is why the authors (Honzíková, Fadrhonc, and Krotký, 2024) are working on creating a digital version.

To evaluate the test, all points per each category are recorded in a box and summed up. Theoretically, the maximum score of the TSD–Z test is 72 points.

Respondents

The respondents were primary school students, with a random selection from each year group. In total, there were 330 respondents. The testing was anonymous, and parents consented to the testing. The research was conducted in 2023.

Discussion and interpretation of results

The results from the Urban's Test of Figurative Thinking were processed by using the *ANOVA* program.

Table 2 and Graph 1 measured values in individual classes.

Table 2. *Comparison of interclass differences*

Anova: one factor

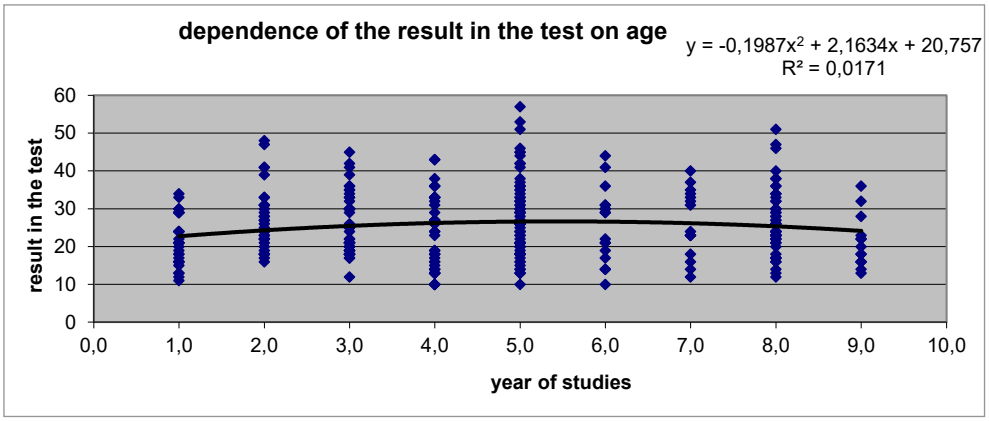
Factor

selection	*number*	*total*	*average*	*scatter*
1.class	30	641	21,36667	42,72299
2.class	35	944	26,97143	68,96975
3.class	48	1235	25,72917	61,86126
4.class	43	996	23,16279	95,33001
5.class	77	2103	27,31169	102,2174
6.class	17	439	25,82353	93,02941
7.class	15	395	26,33333	78,95238
8.class	51	1358	26,62745	73,67843
9.class	14	294	21	46,76923

ANOVA

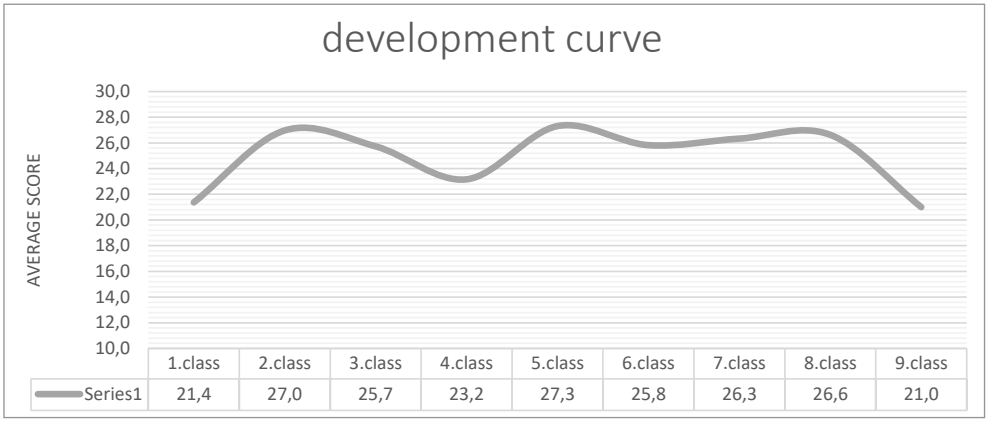
ource variabi	*SS*	*difference*	*MS*	*F*	*value P*	*F krit*
between s	1438,674	8	179,8343	2,295344	**0,021059**	1,967289
all selectio	25149,52	321	78,34742			
in total	26588,2	329				

conclusio At a significance level of 0.05, we can reject the hypothesis of no differences between groups.
This result does not say anything about the time evolution of the mean value, it is only a confirmation that at least for one pair of grades there is a convincing difference (logically, the difference between the 1st and 5th grades...)..



Graph 1. *Graphical comparison*

If we illustrate the results with a simple development curve, we obtain the following pattern:



Graph 2. *Trend curve of measured values*

The results showed decreasing values from grade 5 onwards. The reason why this is so could be a topic for further research.

A comparison of the values measured for boys and girls (Table 3) showed a better graphical expression of creative thinking in boys, which was also confirmed in the PISA tests.

e two-sided alternative is equal to approx. 0.07, i.e., at the 0.05 level, we cannot reject the hypothesis of the absence of gender differences in the mean value.

The hypothesis remained unconfirmed. The results cannot be generalized due to the number of respondents, but other research (Urban, 1991; Torrance, 1969; Honzíková, 2008, 2015; Novotný & Honzíková, 2014) has yielded similar results.

Table 3. *Comparison of measured values for boys and girls*

Two-sample t-test with equality of variances		
	boys	girls
average	26.39891	24.63924
scatter	79.66967	79.07285
observation	183	158
common variance	79.39326	
hyp. difference medium values	0	
difference	339	
t stat	1.818509	
P(T<=t) (1)	0.034934	
t krit (1)	1.649361	
P(T<=t) (2)	0.069869	
t krit (2)	1.966986	

The results raised the question of how Czech pupils would have fared if Year 5 pupils had been selected for comparison in the PISA tests. We may ask: Why did the values drop for pupils in the final grades? All this would be a topic for our further research.

There is no statistically significant difference between boys and girls (the *p*-value for thFor now, we can only guess at the causes of the decline in creativity among 15-year-olds. We do not know whether it is the school system that leads students only to memorize and not to think creatively, or whether these students are afraid of being evaluated by a society that expects knowledge and not their own judgment, or whether students of this age are more critical of themselves than younger students. However, further research may show that the cause of the decline in creative thinking is the influence of digital technologies, which often lead students only to consume the content and not to think creatively. Some of these causes have already been revealed by research conducted by Honzíková (2015), Novotný (2012), and Lokšová (2001). These studies confirmed that the school system, or rather the teaching methods, are behind the decline in creative thinking.

What is certain, however, is that it is necessary to create the conditions for pupils to develop creative thinking and to include the appropriate educational strategies throughout their primary schooling. In the Czech education system, this means reviewing the *Framework Educational Programs* not only for primary education but for all levels of education. Emphasis should be placed not only on knowledge but also on other competencies not yet applied, such as creative thinking.

Key competences in primary education in the Czech Republic

To have competence means that a person (pupil) is equipped with a whole complex set of knowledge, skills and attitudes, in which everything is connected so advantageously that, thanks to it, a person can successfully cope with the tasks and situations he/she gets into in studies, at work, or in personal life. To have a certain competence means that we are able to orient ourselves appropriately in a natural situation, to perform the appropri-

ate actions, and to adopt a beneficial attitude. Primary school pupils acquire different competencies during their studies (https://msmt.gov.cz/file/58196/).

The Czech education system has elaborated competencies for each level of education. For primary education, these are learning, communication, personal and social, citizenship and sustainability, entrepreneurial and work, problem-solving, and cultural and digital competencies.

However, these competencies need to be innovated in order to meet the requirements not only of today's digital society, but also to prepare for life in the Industry 5.0 era.

Here, creative thinking can be considered one of the most important competencies, as the future generation must be able to adapt to the changing conditions in the Industry 5.0 era, where knowledge and digital literacy alone will not be sufficient.

Innovative competences in education for the future

The direction of the Industry 5.0 era implies that there is a need to focus on acquiring competencies applicable to this era already in primary education. Specific competencies will be needed that include technical skills, but, above all, creative thinking and social skills. These competencies will enable people not only to work very effectively with new technologies but also to create and innovate sustainably and ethically. According to various authors (Cedefop, 2020; Pacher, Woschank, and Zunk, 2023; Earp, 2024), the core competencies are the following:

Technical competences

Digital literacy is the ability to use digital technologies and tools effectively, including advanced software and hardware systems.

Programming and coding is the ability to write and understand the code, which is essential for working with AI, robotics, and automation.

Data analytics is the ability to collect, analyze and interpret large volumes of data to support decision-making and production optimization.

Cyber security is the knowledge of techniques and tools to protect systems and data from cyber threats.

Creative and innovative competencies

Creative thinking is the ability to generate new and innovative ideas to improve processes, products and services. Design thinking is an approach to problem-solving that focuses on understanding user needs and designing solutions that are user-friendly and effective.

Flexibility and Adaptability is the ability to adapt quickly to new technologies and working conditions.

Critical thinking and problem-solving

Analytical thinking is the ability to break down complex problems into smaller parts and systematically find solutions. Strategic thinking is the ability to see things in a broader context, plan ahead, and make decisions that have a long-term impact.

Social and Emotional Competence

Emotional intelligence is the ability to recognize, understand and manage one's own emotions and those of others, which is important for effective collaboration and team leadership. Communication and collaboration are the ability to communicate effectively and the ability to work in teams, often remotely, by using digital tools.

Intercultural competence is the ability to work in a multicultural environment and to understand different cultural perspectives and practices.

Sustainability and ethics

Sustainability thinking is the ability to consider the environmental and social impacts of decisions and to look for ways to improve the sustainability of production processes.

Ethical thinking is the ability to recognize and address ethical dilemmas associated with using advanced technologies such as AI and robotics.

Competence in creative thinking

Competence in creative thinking can be defined as the ability of an individual to generate new and original ideas, to solve problems in an innovative way, and to approach challenges with a flexible mindset. After studying the definitions provided by many authors (Urban, Jelen, and Kováč, 2003; Amabile, 1983; Torrance, 1969; Taylor, 1975; Ulger, 2015; Gürlen, Cihan, and Dogan, 2019; Markovič, 2012, etc.), we selected those aspects of creative thinking that can be considered the most important:

- Originality and innovation, i.e., the ability to generate new, novel ideas that differ from conventional solutions.
- Flexibility of thinking, i.e. the ability to adapt to new situations and changes, to perceive new information, and to adapt to it.
- Analytical and synthetic thinking is important for breaking down complex problems into smaller ones in order to find connections and individual solutions.
- Healthy risk-taking is the ability to use new ideas, even at the cost of failure, to push the boundaries of possibility.
- Motivation and perseverance are important for overcoming obstacles and knowing how to start again after the first failure.
- Collaboration and communication are very important, just for pushing the boundaries in idea generation and developing creativity.

The definition of creative thinking competence, therefore, includes a combination of intellectual abilities, personality traits and social skills that enable an individual to generate new and useful ideas and approaches.

Subjective preconditions and objective conditions for the development of creative thinking

What influences the development of creative thinking during the school years, and where to start with education for creative thinking? Some authors (Lokšová et al., 2001; Maňák,

1998; Pelcerová & Honzíková, 2016, etc.) agree that it is the educational strategies based on subjective assumptions and objective conditions for the development of creative thinking that are linked to the environment and educational methods. In the following, we will list at least the most basic subjective preconditions and objective conditions for the development of creativity.

Subjective conditions for the development of creative thinking

Perception, as one of the subjective preconditions, is a cognitive process that captures what is acting on our sensory organs in the present moment. One chooses from a multitude of acting stimuli and focuses one's perception on what is somehow important, significant, and related to our needs and interests, according to our experience.

It is up to the teacher to guide the pupils to become more effective perceivers, to become more sensitive, and to perceive things in an unconventional, problematic way.

Observation can be considered as another subjective assumption. Observation is the deliberate, purposeful and planned perception of things and phenomena. The aim of this deliberate perception is to penetrate as deeply as possible into the details of things and phenomena and to see them in certain contexts.

The teacher should guide the pupils in deliberate observation, and the sensitivity of observation can be increased through practice. For example, field trips can be considered as observation practice in the classroom.

Imagination can be considered an equally important subjective prerequisite. Imagination is either images that reproduce (either faithfully or imperfectly, incompletely with errors) something that is familiar to us, that we have perceived in a given form, or these are images of something relatively new to us. In the first case, we speak of the imagery of memory; in the second case, it is imaginative imagery. Imagery, which is linked to interests, knowledge, skills and abilities, as well as experience, also plays an important role in the formation of imagery. In imagery, new combinations of temporal connections that have been made in previous experiences are created. It is, therefore, closely linked to practice.

The teacher can develop imagination in the pupil through problem-based tasks and learning projects (Novotný, 2012). In these tasks, not only knowledge but also skills and imagination are used.

Personality traits such as curiosity, i.e., a natural desire to discover new things and seek answers to questions, can also be considered very important. A healthy self-esteem and motivation to learn and create are also important. The teacher can develop personality traits through well-chosen problem-based tasks. *Cognitive skills* are acquired by pupils at all levels of education. Intellectual skills can be developed through well-chosen tasks where pupils learn to analyze information, think synergistically and combine knowledge. Memory, i.e., remembering important information, also plays an important role.

Objective conditions for the development of creative thinking

Objective conditions affecting the development of creative thinking can be divided into the family environment and the school environment (Pelcerová et al., 2016).

In the *family environment*, it is mainly the support of parents and their educational values. Parents' attitudes towards learning and creativity have a major influence on the development of children's creative abilities.

In the *school environment*, the development of creative thinking is mainly influenced by the quality of teaching, the material equipment of the school and the atmosphere in the classroom, where the relationship between the teacher and the pupil, the motivation of pupils, respect for the personality of the pupil, developing curiosity and willingness to take healthy risks, and supporting creative individuals can be considered the most important aspects.

The educational strategies of the method are important for developing creative thinking, which has been demonstrated by the pupils who achieved the highest scores on the PISA tests. These strategies can include interactive and experiential learning, such as project-based learning, experimentation, and hands-on activities. It is also important to promote independence and autonomy, which is guaranteed by individual projects and freedom to learn. The development of critical and divergent thinking is guaranteed by open-ended questions, discussions and debates.

Various researches (e.g., Pelcerová et al., 2016) demonstrate the importance of the cultural and social environment for developing creative thinking. Cultural attitudes towards creativity, as well as gender attitudes, play a major role. The availability of cultural and educational resources is also very important. It is influenced by social and economic factors which also affect the availability of digital tools and platforms.

The development of creative thinking in primary school students, therefore, depends on a complex set of factors that together shape an environment that fosters creativity and innovation.

Why creative thinking is necessary in working life

Creative thinking is necessary in working life for several reasons, all of which relate to the ability of organizations and individuals to adapt, innovate and improve production processes and products so that to make them efficient, competitive and sustainable. Here are the main reasons why creative thinking is important in working life (Honzíková, 2015; Pelcerová et al., 2016; Pacher et al., 2023):

Innovation and competitiveness

Creative thinking is important for the development of new products and services for the population in order to develop new original products that are better than those of competitors. Creative approaches to solving problems lead to more efficient and innovative work processes to increase productivity.

Troubleshooting

When solving problems, it is necessary to find non-traditional solutions that respond to the changes that occur.

Personal and professional development

Creative work is more interesting for employees and allows for personal development. It is also important to have room for your own opinions and to think flexibly.

Collaboration and teamwork

Creative thinking encourages a diversity of views and approaches that can lead to more innovative results. Effective communication and collaboration is also necessary in creative processes, strengthening collective intelligence.

Strategic thinking and planning

Creative thinking is important for new planning strategies and the organization's vision, as it supports new business models that can better respond to changing market conditions.

Sustainability and social responsibility

The future requires a creative approach that will lead to more sustainable and responsible approaches to production that are more environmentally friendly.

Technological progress

Technological advances are inevitable in any industrial era, and therefore it is necessary to use these technologies creatively, and to innovate the already existing ones.

Creative thinking is, therefore, an essential tool for success and development in working life as it promotes innovation, solving problems, personal and team growth, and adaptation to changing conditions.

Conclusion

Creative thinking is the ability to generate new and original ideas and solutions. It is important because it fosters innovation, which is key to economic growth and competitiveness. In the work environment, creative thinking allows to identify and solve problems in non-traditional ways, which can lead to more efficient and sustainable production processes. Creative individuals often bring new perspectives that can improve team dynamics and collaboration. In addition, creative thinking increases personal satisfaction and motivation because it provides a space for expression and self-actualization. In an era of rapid technological change and globalization, the ability to adapt and innovate is critical to the long-term success of individuals and society. Overall, creative thinking is essential for staying relevant and growing in a dynamic world (Broadley, 2024; Research and Innovation; Croft, 2024).

Learning towards creative thinking is essential to developing the skills necessary for success in the Industry 5.0 era. Creative thinking fosters innovation and the ability to solve problems in non-traditional ways, which, in turn, is key to competitiveness in the job market (Earp, 2024). It enables students to adapt to rapidly changing technologies and envi-

ronments, which is essential in the Industry 5.0 (I4MS) era, where humans interact with various technologies and robots. Creative thinking also increases personal motivation and engagement in education as students learn through their own interests and ideas (Croft, 2024). It promotes critical thinking and the ability to analyze different situations from multiple perspectives. Teaching for creative thinking also develops collaboration and communication because students often work on projects in teams (Research and Innovation, 2021). In addition, teaching for creative thinking is important for developing social and emotional skills because it involves empathy and understanding of others. Overall, teaching for creative thinking prepares students for the complex challenges of the future and enables them to become active creators of their own future in the Industry 5.0 era.

The PISA 2022 results only confirmed the need for systematic development of creative thinking in order to better prepare elementary school graduates for future professional challenges in Industry 5.0. The results also showed that, in most countries, including the Czech Republic, creativity is not systematically developed. And this is a challenge not only for educators, but also for reformers of educational programs.

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Other supplementary resources

https://i4ms.eu/towards-industry-5-0-news-skills-and-capabilities-working-group/

Industry 5.0: Towards more sustainable, resilient and human-centric industry - European Commission (europa.eu)

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