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Fifth-Grade Students' Science Competencies: An Opportunity to Rethink Further Education for Science Competence

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This paper deals with the science competences of fifth-grade students (ages 10 and 11 years) in Slovenia. The science content researched in this study comprises chemical concepts, such as aqueous solutions, states of matter, and nutrition. The science competence and science competencies that elementary school students are supposed to develop are defined. In the following, the concept of attitude towards science and its role in the construct of science competence is explained. The three components of science competencies of the 10- and 11-year-old students were measured using a knowledge test to cover content and procedural knowledge and a questionnaire to measure the attitude of students towards science. The findings reveal that procedural knowledge is the least developed among students. It is also confirmed that attitude components have an important role in interpreting overall science competency test achievements. In the conclusion, the holistic view of the development of science competencies (knowledge, skills, and attitude) is emphasised. Further study of the attitudes towards science in relation to science competence development in a broader way is suggested.

Keywords: elementary school students, science competence, competencies, content knowledge, procedural knowledge, attitudes towards science

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Naravoslovne kompetence učencev petega razreda: priložnost za ponovni razmislek o nadaljnjem izobraževanju za razvoj naravoslovnih kompetenc

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Ta prispevek obravnava naravoslovne kompetence učencev petega razreda (starosti 10 in 11 let) v Sloveniji. Naravoslovne vsebine, vključene v preizkusih znanja v raziskavi, se navezujejo na kemijske pojme, kot so: vodne raztopine, agregatna stanja snovi in prehrana. Opredeljene so naravoslovne kompetence, ki naj bi jih razvijali osnovnošolci. V nadaljevanju sta pojasnjena odnos do naravoslovja in njegov vpliv na konstrukt naravoslovne kompetence. Tri komponente naravoslovnih kompetenc 10- in 11-letnih učencev so bile merjene z uporabo preizkusa znanja, ki je zajemal vsebinsko in proceduralno znanje, ter anketnega vprašalnika za merjenje odnosa učencev do naravoslovja. Ugotovitve kažejo, da je pri omenjeni skupini učencev proceduralno naravoslovno znanje najmanj razvita komponenta naravoslovnih kompetenc. Potrjeno je tudi, da imajo komponente odnosa do naravoslovja pomembno vlogo pri interpretaciji skupnih dosežkov na preizkusu znanja naravoslovnih kompetenc. V zaključku je poudarjen celostni pogled na razvoj naravoslovnih kompetenc (znanje, spretnosti in odnos). Predlagano je nadaljnje raziskovanje odnosa do naravoslovja v povezavi z razvojem naravoslovnih kompetenc na širši ravni.

Ključne besede: osnovnošolci, naravoslovna kompetenca, kompetenca, vsebinsko znanje, proceduralno naravoslovno znanje, odnos do naravoslovja

Introduction

Competences are a construct that is difficult to define in an epistemological sense. The definitions of competences in the existing literature (among others, from the Directorate for Education, Employment, Labour and Social Affairs Education Committee (DeSeCo), 2002; European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019; Illeris, 2009; Mausethagen, 2013; OECD, 2018) define it as an important ability to see and respond in accordance with a situation from the future, which is still unknown from the perspective of the present and cannot be recognised in advance, when competences are developed in the individual. That, in addition to the fact that recommendations are not clear on how competence development should be done on the national level, is why it is challenging to incorporate them into education (Halász & Michel, 2011).

Literature provides a distinction between qualifications and competencies, competences, and literacy. Qualification is the specific knowledge that enables the performance of an individual work (i.e., the profession). Definitions of competencies are centred on functionality, with a focus on the profession and specific knowledge and represent a practical orientation of competences by including all the individual's basic knowledge, skills, abilities, and attitudes (Brownie et al., 2011; Guthrie, 2009). Competences, unlike the first, should represent a set of skills, knowledge, and relationships with sufficient levels of development of critical thinking that enables an individual to succeed in new, previously unknown circumstances or contributes a good starting point and basic knowledge regarding the varied issues of present-day society (DeSeCo, 2002; European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019; Radulović & Stančić, 2017). Comparison between scientific competence and science literacy is difficult and depends on the viewpoint of its use and epistemological background (Holbrook & Rannikmae, 2009; Laugksch, 1998; Miller, 1998; OECD, 2018, 2019a). However, both terms distinguish themselves from a focus on mere content acquisition and instead include the concept of significance, an understanding of the nature of science, the cultivation of individual traits, and the attainment of socio-scientific skills and values (Devetak, 2017; Holbrook & Rannikmae, 2009; Laugksch, 1998; OECD, 2018; OECD, 2019a). In addition, as indicated in both PISA Analytical Frameworks (OECD, 2018, 2019a), specific scientific competencies comprise science literacy in specific contexts requiring a certain grasp of science and technology. For that reason, scientific literacy can also be considered one of the key competences (Rychen & Salganik, 2003).

The Council of the European Union published eight key competences in its recommendation (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019). Simultaneously, all these key competences share the attributes of transferability and versatility.

For our research purposes, the competence in science, technology, and engineering (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019) represents the basis for the development of the competencies model used for measuring students' knowledge, skills, and attitudes. According to the adapted model of competences (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019; DeSeCo, 2002; OECD, 2018, 2019a), every competence predicts a developed database of content knowledge in the field of science, basic skills (procedural knowledge) and of course the attitude component of subject area to which each competence relates.

According to Krnel (2004a, 2004b), scientific skills constitute a crucial and foundational component of all competencies within the realm of science. The author here uses the term 'process skills', but these fall under the segment of procedural knowledge, as opposed to factual knowledge, according to Miller (1998). In the early stages of elementary school education, as described by Krnel (2004a, 2004b), students begin to acquire fundamental cognitive skills. These skills include activities such as sorting, arranging, attributing, scheduling in space and time, and using symbolic systems. As they progress, students further develop abilities related to systematic observation and experimentation, with a focus on conducting impartial and objective experiments. They also gain proficiency in handling information and formulating questions relevant to natural science procedures. By the end of the second three-year period in Slovenian elementary education, students should be prepared to engage in research activities, which involve the skills of prediction, hypothesis formulation, data presentation, and data integration, among others. This set of procedural knowledge is also acknowledged by other authors, including Smart (2017) and van Uum et al. (2016), who collectively highlight key competencies, such as questioning, observing, predicting, sorting, measuring, exchanging ideas, and interpreting gathered data.

The holistic view, indicated by the concept of competences, assumes that functionality, sensitivity, and sociality must be developed in an appropriate proportion in relation to the field of competence development (Illeris, 2007).

Motivation holds a significant position in the decision-making processes concerning specific learning behaviours (*inter alia* Illeris, 2007; Juriševič, 2005; Ryan & Deci, 2000; Schiefele & Rheinberg, 1997). The components of motivation are, therefore, a motivational construct, which can be analysed from the student's learning behaviour or from what the student says.

The often accompanying term 'attitude towards science' is a component that is difficult to measure (Reid, 2006) although important in the observed relationship with both procedural and content knowledge (e.g., Lee & Kim, 2018; OECD, 2018; Zulirfan et al., 2018). One of the fundamental documents in its updated version defines attitude as what it describes as a starting point and mindset when acting and responding to ideas, persons, or situations (European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019). A systematic review of research on interest, motivation, and attitude conducted by Potvin and Hasni (2014) recognises attitude as a construct consisting of three components: cognitive, affective, and behavioural, encompassing inclinations, either positive or negative, towards an object. Juriševič et al. (2010), in their questionnaire of students' attitudes towards Chemistry, suggest two main components to measure: interest and self-concept. The latter is supported by Pintrich and Schrauben's (1992) Social Cognitive model of Student Motivation, in which the student's engagement in learning in school is conditioned by motivational and cognitive components. Student's learning self-concept and interest in learning fall under the motivational components (right there).

Previous research has identified a favourable relationship between students' attitudes towards science learning and their academic achievements in secondary school (Narmadha & Chamundeswari, 2013) and that self-concept was a more reliable predictor of achievement (Guo et al., 2016). A meta-analysis of research on the correlation between science knowledge and attitude towards science (Allum et al., 2008) revealed a modest positive correlation between general attitudes towards science and general knowledge of scientific concepts. This correlation exhibits variability depending on cultural factors and the specific domains of science and technology (*inter alia,* Allum et al., 2008; Guenther & Weingart, 2016; Lee & Kim, 2018).

As mentioned earlier, content knowledge (Miller, 1998) represents the third component of the construct of competences (DeSeCo, 2002; Key Competences, 2002; OECD, 2018). Contents that are discussed in the school environment (and represent the focus of our research on the content knowledge part) are determined by curricula. The Slovenian Curricula for Science and Technology (Vodopivec et al., 2011) provides a wide range of topics to be taught in school. Our research focused on the three basic groups of content: environmental issues, nutrition, and chemical substances and aqueous solutions.

Environmental issues represent an important content in the school subject Science and Technology in Slovenian elementary schools. As some research suggests (*inter alia* Alaydin et al., 2013; Treagust et al., 2016). students need constant reminders that environmental issues are important for them to understand the environment in which they are living. The lower the level of this topic coverage, the lower students' knowledge, leading to adequate levels of concern that can steer their behaviour in the future. A Slovenian study reveals a decline in students' environmental attitudes from the fourth to the seventh grade, whereas altruistic environmental concerns exhibited a notable increase with advancing grade levels (Torkar et al., 2021).

Students' concern about the environment is also related to their personal environment (home situations, parents' and other caregivers' behaviours, parents' education level, family's income, school environmental education experiences, etc.) (Alaydin et al., 2013). According to Salleh et al. (2016), older students than those participating in this research exhibit a considerable degree of knowledge regarding environmental issues and maintain a moderate level of awareness concerning environmental issues.

Similar to the knowledge and attitudes towards environmental issues, nutrition knowledge can be improved through intervention (Lakshman et al., 2010; Wall et al., 2011). Some studies based in schools with low socioeconomic settings indicated that behaviour can be improved with nutrition education (Shen et al., 2015), while others proved the opposite (de Villiers et al., 2016). While the primary aim of the study was not to measure the environmental awareness or nutrition concerns of students, our intention here is to emphasise the significance of these contents, their current integration within the educational process, and the reasons behind the inclusion of these in the science knowledge test.

A cross-age study on the students' (13- to 17-year-olds) understanding of the basics of aqueous solutions and their components conducted by Çalık and Ayas (2005) suggests that students have difficulties describing and using the concepts of solution, solvent, and solute. Additionally, students experience difficulties in bridging the gap between their understanding of matter and everyday life experiences (Blanco & Prieto, 1997; Çalık & Ayas, 2005). Furthermore, some studies in Slovenia have indicated that even among older students (14-year-olds), misconceptions about certain fundamental concepts in chemistry are observed (e.g., Slapničar et al., 2018). Krnel et al. (2003 & 2005) similarly contend that children should acquire an understanding of matter and objects. The process of discerning various substances through actions assists them in uncovering distinct properties. Their research affirmed that children progressively construct more sophisticated schemas, enabling them to differentiate between extensive and intensive properties and, consequently, between objects and matter. As they accumulate more experiences, they become proficient in identifying properties of matter that remain consistent regardless of the matter's form and classifying it accordingly. In addition, according to Urbančič and Glažar (2012), older students can provide accurate descriptions and explanations of experiments after a certain period, provided they possess a genuine comprehension of the fundamental scientific concepts involved. The students' descriptions of their experiments can serve as a means to pinpoint particular misconceptions.

According to Chang and Hsin (2021), self-explanation triggers inferences that students generate independently to comprehend the information, thus stimulating independent thinking and prompting them to delve deeper into the provided information. This technique can be employed to address students' knowledge gaps in a particular science domain (Chang & Hsin, 2021). Self-confidence assessment and self-explanation require that the student do similar; in the first case, the assessment of how strongly he/she believes in the solution proposed, while in the second case, he/she must also be able to explain it. Therefore, it is important for a study with a focus on measuring knowledge achievement to check the self-confidence and self-explanation abilities of students.

Research problem and research questions

Science competences represent the centre of our research problem. No research with a direct focus on the array of science competencies (with the focus on specific chemical concepts) of 10- and 11-year-old students has been done in Slovenia or, as far as the accessible literature is regarded internationally. In contrast, research has been conducted concerning scientific literacy and accompanying attitude components (e.g., OECD, 2019a, 2019b), correlations between attitudes towards science learning and procedural knowledge (e.g., Zulirfan et al., 2018), correlations between attitudes towards science learning and level of scientific knowledge (e.g., Lee & Kim, 2018), and attitudes toward science and perceptions of the nature of science among elementary school students (e.g., Toma et al., 2019). Additionally, a systematic review has been conducted focusing on interest, motivation, and attitudes towards science and technology at the K-12 level (Potvin & Hasni, 2014). We should also highlight another study from Slovenia, which focused on a more specific subset of science competence. The primary objective of this study was to investigate whether project-based learning offers more favourable conditions for enhancing students' skills when compared to conventional instructional methods (Pešakovič et al., 2014). Most of these studies focused on the competences of students older than those of our participants. Therefore, no specific suggestions were yet articulated on 1) which science competencies should be developed with students at age ten or eleven and 2) what is the most appropriate way of identifying them. Hence, the primary objective of this paper is to assess the science competencies of a specific group of students. Following the fundamental theoretical construct of competences being comprised of three components: knowledge, skills, and attitudes (DeSeCo, 2002; European Commission, Directorate-General for Education, Youth, Sport and Culture, 2019; OECD, 2018, 2019a); these are recognised as dimensions within which we should measure science competences of 10- and 11-year-old students. The common set of factual knowledge of specifically selected chemical concepts in a science context, science skills achievement and a component of attitude towards science is what is assumed to constitute science competencies of 10- and 11-year-old students.

Following the research problem, the main research questions are:

1. What is the overall level of fifth-grade (10- or 11-year-old) students' science competence, and are there statistically significant differences in science competence between male and female students?
2. What is the nature of students' attitudes towards learning science when they are grouped according to their overall achievements in science tests?
3. Is there a statistically significant correlation between students' confidence level in correctly solving the specific task and their science knowledge test measuring content and procedural knowledge achievements?

Method

Participants

The research was conducted in two schools in the Central Slovenian region. The sample consists of four mixed-gender classes of fifth-grade students. A different teacher has been teaching every class. Altogether, 77 fifth-grade elementary school students participated in the study. Of these, 34 (44.2%) were female, and 40 (51.9%) were male students. Three students did not give information on their gender. Most participants were between the ages of 10 (48.1%) and 11 (48.1%). There were two (2.6%) students aged 12. It should be noted that the older students were repeating the fifth-grade programme. One student did not give information on his age. Students were invited to voluntarily take part in the study, and written consent from their parents or caregivers was obtained for their child's involvement in the research.

The elementary school programme in fifth grade requires three school hours (45 min) per week in the subject of Science and Technology. Lower-grade students (from first to third grade) have three school hours in the subject Learning about the Environment. In fourth grade, students also have three hours of Science and Technology per week. Therefore, students have already attained a certain level of experience with experiments, observing and discussing different natural phenomena, and similar skills. At this age, students should be familiar with basic concepts in environmental issues, nutrition, and chemical substances and aqueous solutions. For comparison, students in fifth grade have four hours of Math, three hours of Sports and five hours of Slovene Language per week.

Instruments

In this research, five sets of variables were measured: the student's individual interest in the subject-specific learning field, the student's self-concept for the subject-specific learning field, the student's science content knowledge, the student's procedural knowledge, the student's confidence level in solving the specific task in the achievement test, and the gender. The latter acts as an independent variable.

Independent variables questionnaire was incorporated into the science knowledge test (SKT). It measured students' content knowledge and their scientific skills. The second instrument was the Student's Attitude towards Science Questionnaire (SASQ), which measured students' individual interest in science and their self-concepts in science.

Science knowledge test (SKT)

The assessment, which assesses both content knowledge (CK) and procedural knowledge (PK), consists of ten tasks. Each of these tasks is broken down into smaller subtasks to facilitate evaluation. In this context, each subtask corresponds to one of Bloom's taxonomy levels, as outlined by Anderson et al. (2001=. These levels can be categorised into three groups: the first level involves remembering, the second level encompasses understanding and applying, and the third level encompasses analysing, evaluating, and creating. As mentioned earlier, our research focused on the three basic contents. An example of the task covering aqueous solutions is shown in Figure 1. An example of the task covering nutrition is in Figure 2, and an example of the task covering environmental issues is in Figure 3.

The knowledge test had a total of 42 points as the maximum achievable score. Out of this total, students could earn 14 points in tasks at the first level, which corresponds to 33.3% of the total score. In the second-level tasks, students could achieve 25 points, making up 59.5% of the total score. Lastly, in the third-level tasks, students had the opportunity to earn 3 points, constituting 7.1% of the overall score. Shares of different taxonomy levels are based on the model suggested by Razdevšek–Pučko (2002). In the self-evaluation tasks, students needed to evaluate their confidence in their answers for every task and potential subtask (i.e., twenty-two times during solving the knowledge test). All items consist of a five-point scale about their confidence level. The scale ranges from not confident at all (1) to completely confident (5).

Figure 1

Example of Task No. 3: content on aqueous solutions.

Task No. 3

Below different claims are listed. Circle whether you agree with a single statement or not. Correct the allegations that are incorrect. If the correction is not needed, enter the "/" sign in the blank space. Any choice or correction should be also explained.

Water is an excellent solvent, as various substances dissolve in it: sugar, dyes, salt ... YES NO

CORRECTION	ARGUMENT

How confident are you in your solution to the task?

1 2 3 4 5

Figure 2

Example of Task No. 6: content on nutrition.

Task No. 6

Read the text. Answer the question by circling the letter before the correct choice of menu. Write a short justification of your choice on lines.

Josh is a fifth-grader who has a very busy schedule. After his school, he has regular basketball training at the basketball club three times a week, and he has music school lessons twice a week. With all the responsibilities, of course, he must also do his regular homework, study, and spend some free time with peers.

Below you have his afternoon schedule for Wednesday. What meal do you recommend for lunch that day?

First, circle the correct choice of the menu offered and then justify it.

WEDNESDAY	LUNCH
end of lessons: 13.45 lunch: 14.10 (at home) basketball training: 15.00-17.00 homework: 17.40-18.40 revision of school lessons: 18.45-19.30 dinner: 19.30 free time: 20.00-20.30 preparing for bed: 20.30 bedtime: 21.00	**A** **MENU 1** beef soup salad with pieces of roast chicken fruit and cereal bar **B** **MENU 2** pizza four seasons ice-cream **C** **MENU 3** broccoli soup potato with flat meatballs pancakes with chocolate spread

Justification of your choice:

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How confident are you in your solution to the task?

1 2 3 4 5

Figure 3

Example of Task No. 8: content on environmental issues.

Task No. 8

Read the text. Find the information that the assignment asks you for and present it with an appropriate diagram. Circle the letter before answering the question asked.

How much water do we consume each day?

Every Slovenian consumes an average of about 150 liters of water per day.

While executing daily habits and needs, we don't even think about how much water we consume. We only use about 4 liters of water per day for cooking and drinking, and as much as 32 liters of drinking water per person per day for flushing the toilet. On average, an adult consumes 55 liters of water a day for a shower, but if we do not close the water during the shower, we can use up to 140 liters of water in five minutes. When manually washing the dishes after lunch, we consume from 30 to 40 liters of water. However, 50 to 300 liters of water are used to wash the car.

Water consumption fluctuates greatly throughout the day - the highest consumption is registered in the middle of the day between 12 pm and 2 pm, and the lowest between 3 am and 5 am.

(acquired from Grinii: http://www.grini.si/grinipedia/koliko-vode-porabimo-vsak-dan, 18. 5. 2018)

What is the average daily water consumption per person for each job?

How confident are you in your solution to the task?

1 2 3 4 5

The validation of the SKT was assured via the examination of the instrument by a researcher in the field of science education and two science teachers (content validity and criterion validity). The instrument was checked for internal consistency (Taber, 2017). In the study, the Cronbach alpha coefficient for the knowledge test scale (10 items) was .85. The Cronbach alpha coefficient for the six-item scale for content knowledge was .81, and it had a mean inter-item correlation of .99. The Cronbach alpha coefficient for the four-item scale for procedural knowledge was .82, and it had the mean inter-item correlation of .93. For the confidence level scale (10 items), the Cronbach alpha coefficient was .95.

As mentioned, SKT was comprised of tasks measuring PK and CK. There were four tasks measuring students' PK. Task No. 2 required students' skill in sorting; Task No. 8 required students' skill in handling information, presenting and interpreting data. Task No. 9 required students' skill in handling information and drawing conclusions. Task No. 10 required students' skill of experimentation. There were six tasks measuring students' content knowledge. The structure of the SKT from the content point of view is presented in Table 1. The classification of tasks, as shown in Table 1, allowed for an even representation of content sections as well as the distribution of various types of tasks throughout the knowledge assessment. Due to the practical nature of the content, environmental issues were examined in tasks assessing PK. The remaining content sections facilitated a more reliable assessment at the first taxonomy level. Similarly, such a knowledge assessment structure allowed for a gradual increase in complexity in the last two tasks.

Table 1

The structure overview of the SKT

Task No.	Type of knowledge tested in the item	Topic	Taxonomy level of the task
1	CK	properties of substances	2
2	PK	properties of substances, classification	2
3	CK	aqueous solutions	1 & 2
4	CK	aqueous solutions	2
5	CK	states of matter	2
6	CK	nutrition	2
7	CK	properties of substances	1 & 2
8	PK	environmental issues, interpreting the obtained data	2
9	PK	environmental issues, interpreting the obtained data	2 & 3
10	PK	environmental issues, planning an experiment	3

Student's Attitude towards Science Questionnaire (SASQ)

The adapted 15-item Attitude towards Science Questionnaire (Juriševič et al., 2010) was applied to measuring attitudes, which comprised two sets of items: one for students' individual interest (see Fig. 4) and another for their self-concept (see Fig. 5) towards science. All items consist of a five-point scale about individual interests or self-concept. Both scales range from strongly agree (5) to strongly disagree (1). The Questionnaire's Cronbach's Alpha is .93 for individual interest and .90 for the self-concept scale.

Figure 4
Example of an item measuring students' self-concept.

8	In Science and technology, I learn the content very quickly.	5	4	3	2	1

Figure 5
Example of an item measuring students' individual interest.

13	Everything associated with science is drawing my attention.	5	4	3	2	1

Research design

The research followed a non-experimental and descriptive design, taking place in May 2018. All instruments were applied anonymously in classes in both elementary schools. Before the application of the instruments, signed parental or caregiver consents for participation in the research were collected. Those students whose parents or caregivers did not agree for their child to participate in the study were excluded from the final sample.

Participating students had the same conditions for completing the SASQ and the SKT. SKT was the first instrument applied, followed by the SASQ. Participants were informed that the data would be used for research purposes only, and the main objective of the study was explained. The students completed the SKT in 60 minutes. They had 15 minutes available for the SASQ.

The collected data underwent analysis using SPSS Version 22. Descriptive statistics were applied to reveal the level of science competence~~s~~ (knowledge, skills, and attitude towards science). To determine the differences in mean scores between groups based on gender (distribution of scores did not significantly differ from a normal distribution, as determined by the Kolmogorov-Smirnov test; female students $D(34) = .13$, $p = .16$, and male students, $D(40) = .09$, $p = .20$) the paired-sample t-test was used. To determine differences between CK and PK achievements (distribution of scores for PK did significantly differ from a normal distribution, according to the Kolmogorov-Smirnov test; CK achievements $D(77) = .08$, $p = .20$, and PK achievements $D(77) = .11$, $p < .05$), the Mann-Whitney test was used. Potential differences between average confidence level in CK tasks and average confidence level in

PK tasks (distribution of scores for both groups were significantly different from normal distribution, according to the Kolmogorov-Smirnov test; confidence level in CK tasks $D(77) = .16$, $p < .001$, and confidence level in PK tasks $D(77) = .12$, $p < .05$) were determined using the Mann-Whitney test. Potential differences between average self-concept and individual interest in science (distribution of expressed levels of specific attitude component were significantly different from a normal distribution, according to the Kolmogorov-Smirnov test, self-concept level $D(64) = .18$, $p < .001$, and individual interest level $D(64) = .12$, $p < .05$) were also determined using the Mann-Whitney test.

For determining the correlation between students' self-confidence and their SKT achievements, Pearson's coefficients were calculated. The same was done to determine the correlation between students' attitudes towards science and their SKT achievements.

Participating students were then grouped based on their SKT achievements. Students' categorisation into three groups based on their overall performance in the knowledge test was determined using statistical formulas. Group 1 comprised students with lower than $M - 1$ SD points, indicating poor overall science knowledge. Group 2 included students who scored between $M - 1$ SD and $M + 1$ SD points, representing average overall science knowledge. Group 3 consisted of students who scored above $M + 1$ SD points on the SKT, signifying superior overall science knowledge. An assumption of normality for some subsamples of data was violated using the Kolmogorov-Smirnov test. The level of reported individual interest in learning science in the group with poor overall science knowledge, $D(13) = .33$, $p < .001$, and the level of reported self-concept in the groups with poor overall science knowledge, $D(13) = .31$, $p < .05$, and with average overall science knowledge, $D(35) = .19$, $p < .05$, were significantly non-normal. An assumption of homogeneity of variance was also violated. For self-concept levels, the variances were significantly different in the three groups, $F(2, 55) = 7.31$, $p < .01$. Therefore, the Kruskal-Wallis test as a non-parametric alternative for One-Way ANOVA was conducted to explore the influence of these groups on attitude towards science. Statistical significance was defined as a minimum criterion for all computed mean differences, with a significance level set at $p \leq .05$. The findings are also presented with corresponding effect sizes. T-test results are reported with Cohen's d, results of Kruskal-Wallis test are reported with η^2.

Results

The results are listed according to the research questions. Every subtitle refers to one research question in the same order as listed in the Research Problem and Research Question parts of this study.

The overall level of fifth-grade students' science competence and differences in science competence between male and female students

The overall SKT score was compared according to gender differences to determine if science competence is significantly different between male and female fifth-grade students. The results show that there are no significantly different levels of developed overall science knowledge (expressed in %) between males and females, but female students are higher than male students on average score. There are also no significant differences in achievements in CK tasks between males and females nor in PK tasks between males and females. For more information, see Table 2. Nevertheless, it seems noteworthy to mention the slightly superior achievement of male students in PK tasks, unlike the otherwise predominant female students in CK task achievements. There are no significant differences between male (M = 7.85; SD = 2.90) and female students (M = 9.21; SD = 3.12) [$t(72)$ = 1.94; p = .06] when comparing individual knowledge test results from tasks on Level 1. As before, it should be noted that in the group with superior overall science knowledge, male students performed slightly better in the third-level tasks (see Table 3).

Table 2

Differences between male and female students' achievements in SKT (overall, CK and PK)

SKT achievements	Gender	*M*	*SD*	*t*(72)	*p*
overall	Female	37.86	14.94	1.24	.220
	Male	42.33	16.15		
CK	Female	43.86	19.77	1.07	.287
	Male	48.75	19.22		
PK	Female	25.96	19.41	1.03	.309
	Male	21.60	16.76		

Table 3

Differences between male and female students' achievements in individual group comparisons

Group	Gender	*N*		Students' achievements in relation to the level of the task in SKT (expressed in %)		
				1	2	3
Poor overall science knowledge	Female	8	Mdn	35.7	14.0	.0
			IQR	30.4–42.9	12.0–15.5	.0–.0
	Male	9	Mdn	28.6	12.0	.0
			IQR	28.6–39.3	4.0–20.0	.0–.0
Average overall science knowledge	Female	19	Mdn	71.4	36.0	16.7
			IQR	64.3–85.7	28.0–38.0	.0–16.7
	Male	26	Mdn	57.1	34.0	16.7
			IQR	50.0–73.2	26.0–38.0	.0–33.3
Superior overall science knowledge	Female	7	Mdn	85.7	56.0	16.7
			IQR	85.7–100.0	48.0–60.0	.0–33.3
	Male	5	Mdn	71.4	56.0	33.3
			IQR	64.3–92.9	53.0–61.0	16.7–33.3

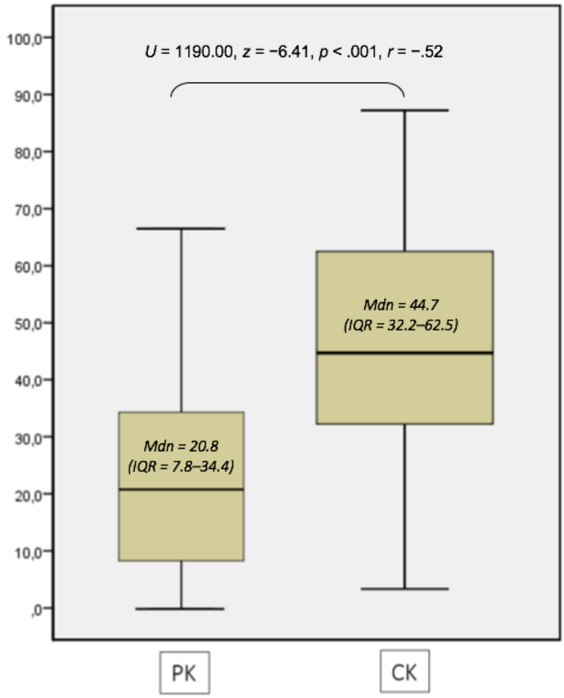
Note. The numbers in the column heading represent Bloom's taxonomy level: number 1 signifies the first level, encompassing remembering; number 2 signifies the second level, encompassing understanding and application; number 3 signifies the third level, encompassing analysis, evaluation, and creation.

Similar results also occurred in the attitude dimension of students' competence. There are no significant differences in self-concept between male (M = 4.02; SD = 1.12) and female (M = 3.67; SD = 1.40) students [$t(61)$ = -1.08; p = .29;] nor in individual interest in learning science between male (M = 3.85; SD = 1.16) and female (M = 3.34; SD = 1.19) students [$t(61)$ = -1.73; p = .09;]. Nonetheless, male students also expressed slightly higher self-concept and interest in learning science.

Students' results revealed that there is a large gap in students' achievements (in % of points achieved) between CK and PK tasks.

Figure 6

Students' achievements (in % of points achieved) in procedural knowledge (PK) tasks and content knowledge (CK) tasks.



In the CK tasks, the average percentage of achieved points was higher than in the PK tasks. A large interquartile range suggests there were major differences in achievements in PK tasks with a tendency towards lower values. Students' CK level was significantly higher than students' PK level.

Among tasks that measured CK, students achieved the highest score (in % of points achieved) in Task 4, by which their knowledge of solution chemistry was measured (M = 60.17, SD = 35.47). The task required recognition of the basic concepts that make up a solution and their attribution to substances in a given case. Students' lowest score (among CK tasks) was achieved in Task 6, which required knowledge of health and nutrition (M = 28.25, SD = 26.70).

Among tasks that primarily measured PK, students achieved the highest score (in % of points achieved) in Task 2, by which their process skills of sorting were measured (M = 40.26, SD = 49.36). Students' lowest score among PK tasks was achieved in Task 10, which required designing an experiment to compare the quality of air in different everyday spaces (M = 1.95, SD = 9.74). For more information on individual tasks, see Table 4. Values are presented in percentages to facilitate a comparison of achievements across tasks.

Table 4
Individual results in tasks (in % of points achieved) with means, SD, and short descriptions.

Task No.	CK/PK	Content	*M*	*SD*
1	CK	properties of substances	51.6	31.2
2	PK	properties of substances, classification	40.3	49.4
3	CK	aqueous solutions	45.5	18.4
4	CK	aqueous solutions	60.2	35.5
5	CK	states of matter	39.0	49.1
6	CK	nutrition	28.3	26.7
7	CK	properties of substances	50.3	31.4
8	PK	environmental issues, interpreting the obtained data	21.6	22.6
9	PK	environmental issues, interpreting the obtained data	30.5	27.9
10	PK	environmental issues, planning of an experiment	2.0	9.7

Data comparison of the levels of expressed students' self-concept and students' individual interest in science has shown a slightly higher self-concept. Further analysis revealed that students did not express a significantly higher level of self-concept in science (Mdn = 4.00; IQR = 3.00–4.75) compared to individual interest in science (Mdn = 3.82; IQR = 2.98–4.48), U = 1699.00, z = -1.67, p > .05, r = -.15.

Students' attitude towards learning science when they are grouped according to their overall achievements in science test

First, a correlation was calculated to answer the research question that refers to the level of the correlation between students' attitudes towards science and SKT achievements. The data reveals that knowledge test achievements are strongly and positively correlated to the student's self-concept (r = .542, p < .001). Test performance is also positively related to the student's individual interest, with a coefficient of r = .828, p < .001.

As all the data suggested, there is a certain statistically significant correlation between SKT achievements, self-confidence, and dimensions of attitude, so further research had to be performed. According to the data, a high correlation exists between students' PK levels and both attitude components. The correlation coefficient is r = .334, p < .05 for individual interest and r = .523,

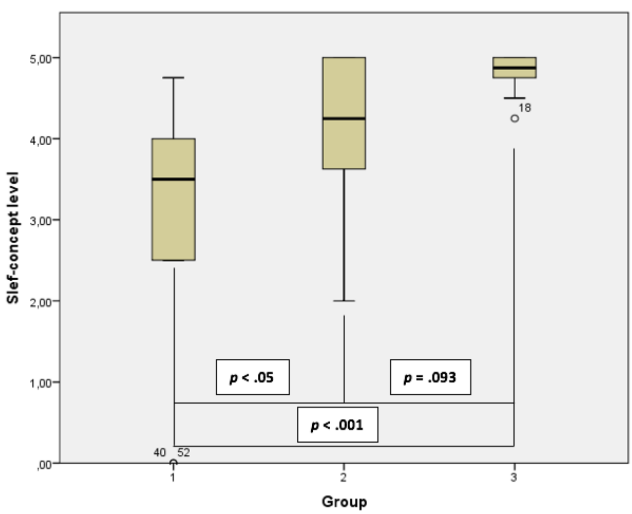
$p < .001$ for self-concept. A high correlation also exists between students' CK levels and both attitude components. The correlation coefficient is $r = .302$, $p < .05$ for individual interest and $r = .419$, $p < .01$ for self-concept.

There are significant differences in the attitude scores between students from groups with different science knowledge. Students with poor overall science knowledge were assigned to Group 1, students with average overall science knowledge to Group 2 and those with superior overall knowledge were assigned to Group 3 (Gp1, $n = 13$: poor overall science knowledge, Gp2, $n = 35$: average overall science knowledge, Gp3, $n = 10$: superior overall science knowledge).

Students' self-concept was significantly different between the groups of students with different overall knowledge test achievements, $\chi^2(2) = 15.740$, $p < 0.001$; $\eta^2 = .25$. Pairwise comparisons using Dunn-Bonferroni tests revealed that there is a statistically significant difference between the group with poor overall science knowledge (Gp1: *Mdn* = 3.50; *IQR* = 2.50–4.00) and the group with superior overall science knowledge (Gp3: *Mdn* = 4.88; *IQR* = 4.69–5.00) and between the group with poor overall science knowledge (Gp1: *Mdn* = 3.50; *IQR* = 2.50–4.00) and average overall science knowledge (Gp2: *Mdn* = 4.25; *IQR* = 3.50–5.00), but the group with average overall science knowledge (Gp2: *Mdn* = 4.25; *IQR* = 3.50–5.00) and the group with superior overall science knowledge (Gp3: *Mdn* = 4.88; *IQR* = 4.69–5.00) are not significantly different from one another (see Figure 7).

Figure 7

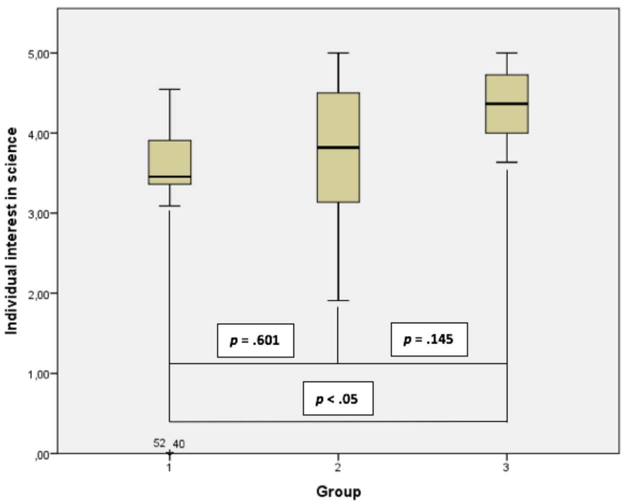
Comparison of self-concept level between groups (1 – poor overall science knowledge, 2 – average overall science knowledge, 3 – superior overall science knowledge)



Similar results can be determined for students' interest in science. It was affected by the groups, $\chi^2(2) = 7.212$, $p < 0.05$; $\eta^2 = .095$, although the effect size is fairly low. Pairwise comparisons using Dunn-Bonferroni tests revealed that a statistically significant difference is only between the group with poor overall science knowledge (Gp1: *Mdn* = 3.45; IQR = 3.23–3.95) and the group with superior overall science knowledge (Gp3: *Mdn* = 4.36; IQR = 3.98–4.80). The group with average overall science knowledge (Gp2: *Mdn* = 3.82; IQR = 3.09–4.64) is not significantly different from the other two groups. For more information, see Figure 8.

Figure 8

Comparison of individual interest in science level between groups (1 – poor overall science knowledge, 2 – average overall science knowledge, 3 – superior overall science knowledge)



Correlation between students' confidence level and their science knowledge test achievements

The results show that SKT achievement scores are statistically significantly correlated with the confidence level expressed by students while solving specific tasks (*r = .668, p < .001)*. This means that the confidence level accounted for approximately 45% of the variation in science knowledge test scores. The average confidence level in CK tasks was significantly higher (*Mdn* = 4.15; *IQR* = 3.42–4.62) than in tasks that required mostly students' PK (*Mdn* = 3.56; *IQR* = 2.78–4.33), $U = 2160.50$, $z = -2.91$, $p < .05$, r = –.23. Comparing this with overall achievements in CK and PK tasks, it seems that students are sensitive enough to doubt the correctness of their solutions for which their knowledge is relatively low.

A high correlation also exists between confidence level and both attitude components. The confidence level is, therefore, statistically significantly correlated with self-concept (r =.474, p < .001) and interest in learning science (r = .694, p < .001). This means that self-concept shares around 22.5%, and individual interest shares 48.2% of the attitude variability in expressed confidence.

Discussion

This research had two primary objectives: 1) initially, to establish the concept of science competence and the specific competencies that should be developed by fifth-grade students attending Slovenian public elementary schools, and 2) secondly, to measure the level of it among fifth-graders. The first research question refers to the level of fifth-grade students' developed science competences. According to the results, students have a deficit in PK rather than in CK. Students expressed that they are less convinced in their answers when the task requires their PK as opposed to their CK. However, they do signify the important fact that, among competencies, skills are not as developed as students' CK. According to the PISA 2018 results with a sample of students older than those in our research (OECD, 2019b), academic performance on their science literacy test was not induced by gender differences. The same finding was confirmed in this study. The results of the present study also do not confirm gender differences in attitudes towards science, but, as mentioned, there are small differences in favour of male students. The PISA 2018 (OECD, 2019b) results also confirm that small difference. Furthermore, the PISA results show that female students were more likely than male students to report positive attitudes towards mastering tasks. In the study by Toma et al. (2019), male students of the same age had better attitudes towards science than female students did.

Comparison between the understandings of concepts revealed that students understand specific concepts differently. These differences can be caused because of various experiences with science learning, different teachers, and different textbooks. As Krnel et al. (2003, 2005) suggest, students at this age do not have equally developed concepts of matter and object, and they do not completely differentiate between different properties. This can be seen from a comparison of achievements in Task No. 2 and No. 5 (Table 4), as the latter requires previously developed concepts. Nevertheless, students achieved the highest scores in tasks that covered aqueous solutions, properties of substances, and states of matter in SKT. The task that covers health and nutrition is among CK tasks, where students' achievements were the lowest. It should be added that the task was relatively demanding. It required the student to analyse a menu; then, it was necessary to conclude the correct answer according to the food composition data of which the student should be aware. Regardless of the viewpoint that nutrition education improves behaviour (Shen et al., 2015) or not (de Villiers et al., 2016), the results suggest that these topics need better coverage. These topics also offer important background for understanding important issues today, such as informed buying decisions, genetically modified organisms, sustainable development, and similar. Results from PK tasks reveal greater differences between task achievements among participating students. Scientific skills are more abstract for this age group of students and seem to be less developed. Additionally, the performance in Task No. 10 prompts reflection on the depth of students' understanding of fundamental concepts in science. As indicated by the study of Urbančič and Glažar (2012), students are unable to provide satisfactory descriptions and explanations of scientific experiments without a sound grasp of these concepts. Of course, this reflection should also consider potential factors such as the lack of practical experience with experimentation in the classroom, the clarity of experiment execution instructions, and other relevant considerations. All these data suggest that certain dimensions of competencies are not as developed (skills) and not as exploited in the process of learning (attitude towards science) as, for example, content knowledge.

The second research question examines the nature of the correlation between science attitude and SKT achievements. In the first step, the overall correlation of knowledge and attitude was measured, but the following tests of correlation were focused on the nature of the observed relationship. The data suggest a high positive correlation exists between the level of PK and students' attitude towards science and between the level of CK and students' attitude towards science. This is in accordance with the work of Allum et al. (2008).

Furthermore, the potentially statistically significant differences in students' attitude dimension of science competence among students from different groups, formed according to students' overall science knowledge test achievements, were checked. As indicated by the findings, there are significant differences between students with different science knowledge.

It can be inferred from the results that competences are better developed within the group with average overall science knowledge and the group with superior overall science knowledge. The results are comparable with the study by Pešakovič et al. (2014). Focusing on the attitude component, these students show higher levels of self-concept compared to the group with poor overall science knowledge. This seems plausible because their knowledge test achievements were higher, and students from Group 1 seem to be aware of their lack of knowledge (according to the results). Nevertheless, the average interest in science learning score is lower than the average self-concept score. Results suggest that self-concept plays an important role in evaluating successful learning (Guo et al., 2016). No conclusion can be made according to the current literature, as different research from various contexts gives different results. Lee and Kim (2018), for example, exposed their finding that, among adults, an important link exists between knowledge and attitude towards science. Of particular interest is the observation from their findings that knowledge, encompassing both content and procedural aspects, exhibits an overall negative association with attitudes toward science. The relationships depend on mediators (predictors of attitude) and the knowledge involved. These differences in results can be attributed to the different ages and cultural backgrounds of participants. Different results are mentioned in other research: with more similar sample characteristics to ours from PISA (OECD, 2019b) and from East Asia (e.g., Hu et al., 2018), with a high level of interest in science but low levels of process skills and academic achievement from Southeast Asia (e.g., Zulirfan et al., 2018) and uniquely correlated variables from South Africa by Guenther and Weingart (2016). All the mentioned research agrees that post-industrial societies increase the negative correlation between the science knowledge level and attitude towards science, whereas, in industrially developing countries, science is seen to be more trustworthy and interesting.

The results support the idea of attitude being a construct of self-concept and interest in the subject-specific field (Juriševič et al., 2010) and support the concept of subject-specific competence being comprised of knowledge, skills, and attitude towards the subject-specific field (*inter alia* OECD, 2018, 2019a; Illeris, 2009).

The third research question inquires about the presence of a statistically significant correlation between students' self-assessments and their level of PK and CK. A high correlation between students' confidence level and their level of science competences implies that students at this age are conscious of their academic success. They seem to be interested in the subject when they feel they have mastered the task given. The last fits the theory of competence motivation by which students, especially at this age, are more motivated in the subjects where they feel competent, with individual interest being one of the intrinsic motivation components. (Urdan & Turner, 2005).

Conclusions

Throughout this paper, the holistic view of the development of science competences is presented. Findings from the research reveal that the overall level of 10- and 11-year-old students' science competences is inadequate and unequally developed. This can be concluded from overall achievements in science competences and the statistically significant differences in students' attitudes towards science from different groups that were formed according to their SKT achievements. An interesting correlation between the level of PK and components of attitude has been observed. It can be summarised that there are no statistically significant correlations between the level of CK and both components of attitude (self-concept and individual interest). Concerning the self-concept, there are differences between low and medium and low and high achievers, but no statistically significant differences between medium and high achievers at the SKT. Statistically significant differences in individual interest in science learning were detected only between low and high achievers.

It can be concluded that students' confidence level and their level of procedural knowledge and content knowledge are strongly and significantly correlated. This suggests that students are conscious about science and that this is reflected positively in their level of science knowledge, and these factors also wield significant influence on students' attitudes toward science learning.

Limitations of this study

It is obvious that this research also has some limitations, which would be sensible to eliminate when planning further research. A qualitative review of our data revealed certain deficiencies in our instruments. The self-evaluation form for students to determine their level of confidence in solving the specific task, as was used in this research, is not appropriate for 10- and 11-year-olds, especially the requirement for justification. Participating students rarely gave useful responses, so these data were omitted from the analysis. Consequently, an important amount of data was potentially lost.

Another limitation can be found on the level of the theoretical basis. Van Uum et al. (2016) and Duschl (2007) define the concepts of scientific literacy and scientific knowledge more precisely and consider the epistemological component of natural science alongside content and procedural knowledge within the realm of natural science knowledge. We did not capture this in our research in any instrument, and we did not check this component. It is also exempt from interpretation.

Another important limitation of our study concerns the number of participating students. Because the knowledge and attitude were measured quantitatively, a larger sample of participating students should be included. Therefore, the small number of participants has had an important impact on the statistical analysis of our data. For that reason, the results may have some limitations in interpreting them as representative, although some important aspects of statistical significance and especially the effect size of this analysis offer further discussion.

Implications for teaching

It is suggested to include well-considered activities in the science lessons instruction that would develop science skills. As data from our research suggest, students are aware (to a certain degree) of their strengths and weaknesses in the construct of their science competences. The component of students' attitudes towards science learning and their level of scientific knowledge are correlated. Therefore, it is important to help students raise the bar of their procedural knowledge via the attitude component and their motivation. This relationship seems to be important, as suggested by the high correlation between the two. In the developmental level at which the students from the sample were, motivation for learning is easier to cause and encourage (compared to older students). Therefore, the learning process should exploit that fact and help them to build competences at all three levels, from knowledge to skills and attitude towards science.

Guidelines for further research

With the attitude component being a key factor in the concept of competence development, it should be reasonable to further research and define its role in this so-called construct of competence. Data from this research show the important role of a student's self-concept in knowledge test achievements. It is strongly suggested that we focus on this component. One of the arguments for that is the fact that self-concept does not change as quickly as individual interest in learning science and is, therefore, more persistent.

Disclosure statement

The authors have no conflict of interest to declare.

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