IDENTIFYING SCIENTIFIC AND NON-SCIENTIFIC CLAIMS IN THE NATURAL SCIENCES

NIKA GOLOB,[1] POLONA AVGUŠTIN[2]
[1] University of Maribor, Faculty of Education, Maribor, Slovenia
nika.golob@um.si
[2] University of Maribor, Faculty of Natural Sciences and Mathematics, Maribor, Slovenia
polona.avgustin5@gmail.com

Abstract The purpose of the research was to establish whether elementary school students differentiate between scientific and non-scientific claims and whether the use of scientific criteria is effective. The study was carried out on 31 eighth and ninth graders from one primary school in Slovenia. Each student had to take a test consisting of ten claims that they had to classify as scientific or non-scientific at their own judgement. The test was followed by a discussion in which six scientific criteria were defined that the students had to use to classify ten other claims as scientific or non-scientific. The results show that there are no statistically significant differences in test performance between eighth and ninth graders and between tests. After a discussion with students, they were found to have many misconceptions. These were successfully overcome by having students express their own opinions and ideas to better understand science and develop the critical thinking needed in adult society.

Keywords:
elementary school,
scientific claims,
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scientific criteria,
science

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1 Introduction

Every day we are exposed to a plethora of information. Some of it is scientifically proven, some not. But how do we distinguish the scientific from the non-scientific? What criteria define science? Shermer (2002) defines science as a set of methods for describing and interpreting observable or completed phenomena, past or present, designed to build tested knowledge open for refusal or confirmation. Scientific myths are common, as we are exposed to scientific issues on a daily basis, and people are curious, we want to know how things work. Some answers can be found very quickly, others with more difficulty, as they are more demanding due to the complexity of a phenomenon and the existence of different aspects or views of this phenomenon (Daempfle, 2013).

2 What Is Science?

When we think of the word science, we probably think of a thick book, a laboratory, a scientist in a white coat and gadgets, like a microscope. This, of course, cannot explain what science is, as it is a broad term that includes the following aspects (Baran et al., 2013; Berkeley University of California, 2013):

- Science is knowledge and a process. It is a process of discovery that allows us to link facts into a comprehensive understanding of the natural world.
- Science is exciting. It is discovering how things worked in the past, how they work today and how they will work in the future.
- Science is useful, as it can be used to discover new technologies, treat diseases, etc.
- Science is in progress, as our knowledge is constantly evolving and expanding. This leads to new questions.
- Science is a global human endeavour, as people all over the world participate in the process of science.

It is useful to know what scientific procedure is, as this helps to identify misleading and untrue claims or statements. This is how we learn to properly analyse and correctly assess many of the questions that arise daily. But before analysing, it is necessary to know how science works. Baran et al. (2013) stress that science is a process based on asking questions. When questions are asked, we look for evidence-based answers, but because not everyone agrees, a debate begins. That is the basic scientific process: ask questions, give answers, debate, review, and ask more questions. So how does science work? Not as it does in most elementary and secondary schools, where students follow certain instructions to perform laboratory exercises. Almost everyone knows what the results of the experiment will be, and what chemicals and utensils will be used. After the experiment, they have to write a report and explain the results of the experiment, which they usually find in a book or in the teacher's explanation during the chemistry class. Thus, in the school process, we usually get the correct result and the evaluation itself is very simple (Baran et al., 2013). Science, however, is not as simple since it is necessary to independently find a correct answer that is not known in advance.

2.1 Scientific Procedure

The scientific process can be divided into several steps, which usually follow one another consecutively. These are (Baran et al., 2013):

- research and discovery;
- information gathering;
- stating hypothesis;
- testing of hypothesis;
- conclusion; and
- analysis within the scientific community.

The first step in science is usually asking questions, observing and initial experimentation. In addition to observing, data collection and experimentation are important, not in order to achieve the final result, but to make it easier to choose between various interpretations and hypotheses to continue the research (Baran et al., 2013).

A hypothesis is a tested statement that is always either adopted or rejected at the end of the study. It must express something unambiguous with a clear approach to testing (Lack & Rousseau, 2016). Opinions and assumptions based on supernatural and mystical explanations that cannot be tested do not fall within the scope of science (Baran et al., 2013; Afonso & Gilbert, 2010). Scientists conduct experiments to test hypotheses. These experiments must be well planned, otherwise the data used may be worthless.

In most experiments, a control group is required. Random errors can be reduced by repeated measurements (Baran et al., 2013). A conclusion or interpretation of the results of the experiment follows. After testing, the hypothesis is confirmed or rejected. If the hypothesis is rejected, it does not mean that the study is finished. Scientists can set new hypotheses, repeat an experiment, or continue to research and seek new evidence that could confirm their hypothesis. Cooperation with other scientists is essential to ensure the best possible interpretation of the functioning of the world and natural phenomena (Berkeley University of California, 2013).

2.2. Scientific Criteria

This paper focuses on six important criteria that determine science and can help students distinguish between scientific and non-scientific claims. They are the following, as summarised from the article "Is it science?" (University Corporation for Atmospheric Research, 2015):

- Scientific is *natural,* subject to *continuous observation and testing.*
- Scientific truth is *temporary,* subject to new discoveries.
- Scientific findings are *uncertain.*
- Scientific findings should be *shared with society.*

Scientific explanations are based on natural laws. Articles published by scientists must be tested and peer-reviewed by the scientific community. Scientists can explore on the basis of their beliefs, but the results may not be adopted in scientific articles. The subject of research can be a car, a battery, mental health, or the weather. In any case, science is usually limited to natural explanations, as these can be scientifically confirmed (Viney, 2007).

Observation of the phenomenon/event must be a planned and targeted activity. It is observed through the senses (hearing, vision, type, smell, taste). Students come to know the concept of a variable through observation, if observing a changing feature. Measuring and observation aids, such as a microscope, a magnifier, a telescope, etc., may be helpful in observing (Ambrožič et al., 2010).

The research must not be influenced by personal beliefs or financial reasons. We must be prepared to accept and correct the errors (Lack & Rousseau, 2016). Rauch (2013) writes: "At the bottom of this kind of scepticism is a simple proposition: we must all take seriously the idea that any and all of us might, at any time, be wrong. Taking seriously the idea that we might be wrong is not exactly a dogma. It is, rather, an intellectual style, an attitude or ethic" (p. 58).

Scientific explanations should be open to new research and evidence (Viney, 2007). Over time, we can find new evidence that changes our understanding. If scientific discoveries are tested several times over time, then that knowledge becomes a theory (Berkeley University of California, 2013).

Science is also uncertain, as we are never 100% certain. Being 99% certain means there is still a 1% chance of being wrong. The weather is an excellent example, as predictions are usually reliable, but with a 90% chance of rain there is still a 10% chance that it will not rain (University Corporation for Atmospheric Research, 2015).

Table 1: Criteria for identification of scientific and non-scientific claims

CRITERIA	APPLIED IN THE SCOPE OF SCIENCE
Natural	Science is limited to studying natural phenomena or mechanisms in the environment we live in.
Testing	Natural phenomena must be tested. Tests (experiments) in science must be predictable and repeatable.
Observation	The phenomenon or event must be detected by human senses or by various devices, such as a microscope or a thermometer.
Temporary	Scientific explanations and findings of phenomena are temporary, as new evidence can be found that changes the understanding.
Uncertain	Science is uncertain, as there is no scientific phenomenon that we are 100% certain of.
Society	Science depends on society. It requires cooperation with other scientists, providing findings in scientific journals, articles, etc.

Source: Adapted from (University Corporation for Atmospheric Research, 2015).

Society plays a major role in science. Sometimes it is good to include other scientists in studies, as they can help us see things from a different angle (Adams, 2013; Lack & Rousseau, 2016). The reasons for publication in established scientific journals is that the community also benefits from it, science can progress faster and more effectively, and new dogmas are subject to scientific review (Lack & Rousseau, 2016).

For the purpose of the study described in the following sections, the criteria summarised in *Table 1* has been adapted on the basis of the literature used. These criteria present a tool for identifying scientific or non-scientific claims for elementary school students.

3 Findings on Learners' Conceptions of the Nature of Science

Daempfle (2013), a university biology professor in Great Britain, believes that we are exposed to scientific questions on a daily basis in almost all areas (e.g., history, science, philosophy). In various countries and among all communities, there are widespread beliefs that are not scientific and are often referred to as pseudoscience. Mugaloglu (2014) emphasises that the intrusion of pseudoscience into science education is a problem in science education today. Scientific myths, which are the result of misconceptions and beliefs, are occurring more and more in our society. There are several reasons why people do not show great interest in science. These are, according to Daempfle (2013): a) the media highlight the greater value of sport and leisure, b) progress in technology is more oriented towards fun than towards teaching, c) the value of hard work has decreased dramatically over the last century, d) poor critical thinking and literacy and e) the mode of teaching at school does not attract students.

Below the authors present some of the research conducted so far in the field of understanding science and non-science, with the aim of better highlighting the studied topic. Different beliefs are somehow an appropriate context for learning the nature of science. Non-scientific explanations appeal to students' interests and are socially and personally relevant to the everyday lives of individuals (Afonso & Gilbert, 2010). Based on a small sample of students Thompson and Logue (2006) state that the older the students, the more difficult it is for them to accept that their perceptions are wrong, while younger students have a more open desire to learn and obtain new information. Younger students also have more or less appropriate and correct perceptions. However, a number of cases were observed, where students were confused by sub-questions. Ten-year-olds feared failure since it was very difficult to get an answer from them. Older students, however, often thought about the question longer before giving their answer. The authors also observed that the responses of the youngest students were based on observation, while the oldest elementary school students, besides observed information, considered their existing knowledge. The researchers also wondered how students accept the fact that their perceptions are wrong. They found that, especially the oldest students, find it very difficult to accept being wrong. Even when their beliefs were rejected by an experiment, they did not give in, suggesting rooted beliefs that are very difficult to change (Thompson & Logue, 2006).

Afonso and Gilbert (2010) examined the beliefs and explanations of university science students and non-science students for "water dowsing", a pseudoscientific method for finding groundwater. Their results show that many students believed in the effectiveness of water dowsing and gave pseudoscientific explanations for it. Moreover, the students were not aware of the demarcation criteria between science and pseudoscience (Afonso & Gilbert, 2010).

In an extensive study on a larger sample (247) of American students, Abraham at al. (1992) found that 28% of all responses indicated poor understanding of chemical phenomena. The authors of the study believe that the vast majority of chemistry teachers rely on the text written in the textbooks and use the interpretation of natural sciences with laboratory work too little (Abraham at al., 1992). The inadequate understanding of students' conceptions of the particulate nature of matter is supported by a literature review by Karataş et al. (2013), in which many research findings suggest that students' conceptions of the particulate nature of matter range from belief in a continuous form of matter to sophisticated ionic and molecular representations. Although students' conceptions often became more sophisticated with age, many student responses still contained inappropriate macroscopic conceptions (Karataş et al., 2013).

According to Akgün (2009), future teachers have difficulty in defining terms, such as dissolving and diffusion, and believe that they derive from misconceptions by their previous teachers. The author therefore suggests that teacher incomprehension should first be eliminated, otherwise misunderstanding spreads further to younger generations (Akgün, 2009). A study by Arias and Davis (2017) examined the learning trajectories of four pre-service teachers of science teaching practice in supporting students in making evidence-based claims during a two-year practice-based teacher education program. One teacher supported elementary students in analysing data in an inconsistent manner, while another teacher developed sophisticated support. The results of this study suggest that elements of the program, such as coherence, facilitate learning. All this has implications for teacher educators (Arias & Davis, 2017); therefore, we could also expect positive effects on students' knowledge and beliefs.

A positive change in better understanding among younger students was observed by Novak and Treagust (2022) as they examined how students develop an integrated understanding of scientific ideas and how they apply their understanding to new situations. When students explore a phenomenon, they need to gather evidence and use scientific ideas and arguments to understand and make sense of the phenomenon. In their study, the authors examined the gradual development of 7th grade students' scientific ideas over four iterations of a scientific explanation of a freshwater system. The authors show that knowing how to use scientific ideas to explain phenomena must be learned, as well as developing an integrated understanding of scientific ideas. The students participated in an open-ended, long-term project-based learning unit in which they created an explanation over time. Novak and Treagust (2022) emphasise that students need opportunities to make claims based on existing evidence and to use scientific ideas to justify why the evidence supports the claim. They also need support not only to understand that they need to incorporate scientific ideas, but also how to incorporate those ideas. It is not enough for students to learn about scientific ideas. Students need to use ideas to understand phenomena, to develop an integrated understanding of scientific ideas, to know how to use those ideas, and to apply that understanding in new situations. Through various iterations of explanation during qualitative research, the students were able to engage in richer discussions using appropriate scientific ideas. The students were also able to better use new knowledge in new situations (Novak & Treagust, 2022).

The difficulties with the nature of science were also observed by Cobern et al. (2022) on a sample of 500 prospective elementary and middle school teachers. They found that during their studies most students considered noncontroversial science to be correct and that almost all acknowledged the provisional nature of science, regardless of what they thought about controversial issues. In his qualitative survey study, Karaman (2022) examined the views of practicing elementary school, physics, and science teachers (750 participating teachers), regarding the distinction between science and pseudoscience in the specific context of astronomy and astrology. The teachers used six different dimensions to distinguish science from pseudoscience: universality, source, verification, methodology, aims, and progressiveness. Many of the teachers' conceptions of science did not necessarily match contemporary representations of the nature of science in the science classroom. The results of this study suggest that teachers should be given opportunities to refine their conceptions of the nature of science in professional development programs (Karaman, 2022). It is advisable for science educators to focus more on the relationship between data and evidence in the classroom that leads to the permanence of scientific knowledge (Cobern at al., 2022). Ferguson (2022) argues that "society can both trust in scientific evidence and question scientific bias in the same space, holding these two seemingly opposite positions in productive tension" and concludes that we should teach students to do the same when using critical realism in science.

Because of these results, systematic and sustained efforts have been made to teach the nature of science. Implicit and explicit teaching approaches have been developed in numerous research studies, as cited in Afonso and Gilbert (2010). In the implicit teaching approach, the effective understanding of the nature of science is the result of guided, hands-on, inquiry-oriented activities. In the explicit teaching approach, the various dimensions of the nature of science are clearly addressed and reinforced through reflective, hands-on experiences with their application. Thus, Afonso and Gilbert (2010) conclude that the implicit approach has had limited success, while the explicit approach appears to be more successful. Lederman at al. (2002) point out that the current state of this line of research calls for a focus on individual classroom interventions aimed at improving learners' beliefs about the nature of science rather than mass assessments aimed at describing or evaluating students' beliefs. Thus, the authors of this paper took the explicit approach in their action research case study with eighth and ninth graders.

The authors believe that understanding science is crucial in contemporary society, therefore they wanted to determine whether it was possible – using scientific criteria (*Table 1*) – to better distinguish scientific claims from non-scientific ones, thus eliminating many of the misconceptions encountered by students on a daily basis. In his book, Deampfle (2013) cites some common scientific and non-scientific claims. Some of these were used in this study.

4 Research

Before beginning the study, the following research questions were posed:

a. Do students distinguish between scientific and non-scientific claims?

b. Do the students' final grades in chemistry affect their ability to distinguish between scientific and non-scientific claims?
c. Is the use of scientific criteria effective in separating scientific and non-scientific claims?
d. Are there any differences between students in the eighth and ninth grade in understanding science and non-science?

4.1 Sample

The study involved 17 eighth-grade students and 14 ninth-grade students from an elementary school in Slovenia, so the results cannot be generalised to the entire population.

4.2 Research Methods

For the purpose of the study, the authors first reviewed the literature relating to scientific and non-scientific claims and based on that prepared two worksheets: one with ten claims, and one with ten different claims and descriptions of criteria defining science. The claims with the arguments are presented in *Table 2* and *Table 3*. The test and implementation of the planned lesson in chemistry class in the eighth and ninth grade of elementary school allowed the use and interpretation of the prepared criteria on science in the evaluation of the claims made. By analysing the results of the completed written worksheets, the authors obtained data that was processed at the level of descriptive statistics using the Excel software tool. The statistical analysis was carried out using SPSS software. For the difference between the two tests (before and after explanation and introduction of criteria) and sections (eighth and ninth grade), a non-parametric statistical χ^2-test of the hypothesis of the same probability was carried out at the level of inferential statistics.

In determining the difficulty index, the authors considered that in dichotomous scoring knowledge tests, the difficulty index is defined as the proportion of students who answer the item correctly. A high difficulty index means that a low level of measurement is required for a positive response (Sočan, 2004, p. 13).

Table 2: The scientific claims used in testing

1.1. Steam condenses in contact with a cold surface. (Criteria: Natural, Testing, Society, Observation)
Condensation is a state when water vapour transforms into a liquid. It can be formed in two ways (Rutledge et al., 2011): 1. The air cools under the dew point. The dew point is the temperature at which condensation occurs. When the warm air comes into contact with the cold surface, it reaches the dew point, and the water vapour condenses. 2. Air becomes saturated with water vapour. Water vapour molecules are far from each other. If the air is saturated with water vapour, these molecules are closer, and when they reach the saturation point, the water vapour condenses.
1.7. Water is at its highest density at 4°C. (Criteria: Natural, Testing, Society, Observation)
Water as a substance has typical properties that are a result of strong bonds between molecules of water, called hydrogen bonds. The result is the high boiling point of water and high specific heat. An unusual characteristic of water is the lower density of ice (solid phase) than water (liquid phase), as the maximum density is at 4°C (Drofenik, 2013).
1.8. Metal is a better heat conductor than wood. (Criteria: Natural, Testing, Society, Observation)
Thermal conductivity is a property of a substance that can be explained by the particles it consists of. Atoms in metals are arranged in crystal structures. As a result, the fluctuation is easier or faster to pass through the substance. Free electrons in metals also contribute to conductivity (Krnel, 2011). They transfer energy from one part to the other even faster with their movement in metal. Metals are therefore good conductors. Insulators such as wood have a very disorderly structure. The basic particles in the wood are large molecules of glucose, which require a lot of energy to fluctuate, so the heat transfers slower than in metals (Krnel, 2011). Many insulators contain air in the intermediate space, which is a bad conductor. Metal is therefore a better heat conductor than wood (Krnel, 2011).
2.1. The Sun heats the Earth's surface unevenly, as this depends on the angle at which the Sun's rays fall. (Criteria: Natural, Testing, Society, Observation)
The amount of heat absorbed depends on the radiation angle of sunlight. The surface is most heated if the sunlight falls perpendicularly, as most of the energy is transmitted to the smallest surface. Surfaces at various inclinations can receive significantly different amounts of radiation and these differences are the main cause of the large differences in vegetation, soil, snow cover, etc. in an environment with a varied relief (Rakovec & Vrhovec, 2000).
1.5. If food is stored in the refrigerator instead of at room temperature, it will deteriorate at a slower rate. (Criteria: Natural, Testing, Society, Observation)
Food goes bad because of the microorganisms present, such as bacteria, yeast or mould. Cold temperatures in the refrigerator do not destroy, but only slow down the growth and reproduction of microorganisms, as these require water, nutrients and a suitable temperature for their growth and reproduction. If the ambient temperature is 4°C or lower, it becomes unfavourable for the growth of microorganisms. They will, of course, continue to grow and reproduce, but slower than at room temperature (Fraser, 2012).
2.5. Green plants cannot survive in eternal darkness. (Criteria: Natural, Testing, Society, Observation)
The main task of green leaves is photosynthesis, during which the leaves can produce up to 200 billion tons of sugars per year, requiring sunlight collected with chlorophyll in chloroplasts (Dermastia, 2007). Besides sunlight, green leaves also need water and carbon dioxide. With the process of photosynthesis, the plant produces sugars. Besides the sugars, it also needs mineral substances for normal growth that are extracted from the soil (Godec et al., 2015).
1.3. Friday's forecast expects showers with an average temperature of 20°C. (Criteria: Observation, Uncertain)
Meteorology is an atmospheric science focused on weather processes and weather forecasting. The variables of the Earth's atmosphere change over time. Events in the atmosphere are very non-linear

and change rapidly. The weather forecast is therefore most reliable 10 to 14 days in advance. Later on, the reliability decreases. (UCAR, Center for Science Education, 2019).
2.2. It was once thought that the number of human chromosomes in the body cells of a healthy person is 48; today, owing to advances in technology, we know there are 46. (Criteria: Observation, Temporary)
The first genetic analysis was conducted in the field of cytogenetics, where 48 human chromosomes were enumerated in the body cell. Later, in 1956, Tjio and Levan (1956) found in their study titled "The chromosome number of man" that there were in fact 46.
2.7. Some plants are carnivorous. (Criteria: Natural, Society, Observation)
Editors of Encyclopaedia Britannica state that some plants are truly carnivorous and almost all of them grow on swamp ground, where the soil is poor with minerals. This is why they are adapted to attract, capture, execute, digest and absorb important animal (especially invertebrates) substances that are not derived from the soil (Encyclopaedia Britannica, 2021).

Note: Claims for the first test had number 1 as a leading number and those for the second test had 2 as a leading number. For each claim, the authors used the criteria defined in Table 1.

Table 3: The non-scientific claims used in testing

2.9. You have to wait at least an hour after having a meal before going swimming. (Criteria: Testing, Society, Observation)
Many people believe that swimming right after having a meal can cause muscle spasms, but there is no evidence to confirm that. This myth is associated with the digestive system as the parasympathetic nervous system, which is a set of nerve fibres that send a signal for blood and energy to come from other parts of the body towards the digestion system. This does not mean, however, that the muscles will not get enough oxygen and nutrients to function normally when swimming (Daempfle, 2013).
2.10. Storing hot food in a refrigerator destroys food. (Criteria: Observation)
Leftovers of hot food are recommended to be stored in a refrigerator to slow down the growth and reproduction of microorganisms. During the process of cooling the food at room temperature, we increase the possibility of growth and reproduction of microorganisms, which can consequently be harmful to our health. The only negative side to storing hot food in a refrigerator is that the refrigerator will use more energy to cool the food to the desired temperature in the refrigerator (Daempfle, 2013).
1.2. My birthday is at the beginning of February so I'm an Aquarius. That means I am loyal and sociable. (Criteria: Natural, Testing, Society, Observation, Uncertain)
Prothero (2013) states in their study that a large number of surveys showed that 20–30% of Americans, Canadians and Britons believe in astrology, but a large percentage of people do not even know the difference between astronomy and astrology. As long as there are at least a few people who believe this, horoscopes will still appear in magazines, and the people who write them will earn well. The bad thing is that people waste time and money, making decisions based on horoscopes (Prothero, 2013). In the absence of any reliable research on astrology, the claim is not scientific.
1.4. I'll be rich when I grow up. (Criteria: Natural, Testing, Society, Observation, Uncertain)
Believing in something without any doubt is not scientific (Jaffe, 2010). If what you believe is not reproducible (tested), then it does not belong in the field of science (Nilsson, 2014).
1.6. Most people believe that dogs do not sweat because they breathe heavily through their mouths when hot and cool down only this way. (Criteria: Natural,Testing, Society, Observation)
Dogs lose most of their heat by breathing through their mouth. The water evaporates from the tongue through the open mouth, resulting in loss of heat. Besides heavy breathing, blood vessels are wider in the heat, causing greater heat loss, especially on the head and ears where the skin is very thin. Dogs still have sweat glands, which are most densely arranged in the area of the paws (Daempfle, 2013).

2.6. Animals are nicer than humans. (Criteria: Observation, Testing)
Daempfle (2013) summarises scientific resources by stating that animals are supposed to help each other and cooperate only because of common genes. What about pet friendliness towards a human? Is this really just kindness, or is it because a person offers them a home and food? Daempfle (2013) states in the book that the objective of the animal is survival. By providing food and living space for animals, we enable them to survive. But in the wild, related rather than unrelated organisms are supposed to help each other (Dawkins, 1976, as cited in Daempfle, 2013).
2.3. Life began 3.5 billion years ago, and nothing will change that. (Criteria: Testing, Society, Observation, Uncertain, Temporary)
According to data gathered so far, life began approximately 3.5 billion years ago (Kambič et al., 2000). This claim is very similar to the eighth claim in the sub-chapter on scientific claims. The difference is that in this claim, we claim that science is not progressing and does not change over time.
2.4. Walking under a ladder brings misfortune. (Criteria: Testing)
Superstition is a belief in something that is not entirely understandable in either its causes or consequences (Martin, 2004). This is a matter of the individual influenced by several factors. Science cannot claim something about a thing if we cannot prove it experimentally (Lack & Rousseau, 2016).
2.8. I've heard it's always sunny in Southern California. (Criteria: Natural, Testing, Society, Observation)
If many people believe in something, that does not mean it is true. Scientific facts mostly have very little to do with the logic or common sense of a crowd of people (Jaffe, 2010). Data (Repe & Brus, 2010) shows the annual rainfall in California, which means that the claim is not scientific, as it is not always sunny in California.
1.9. Coconut oil is better for your health than olive oil. (Criteria: Testing, Society, Observation)
Coconut oil does not contain representative essential nutrients, e.g., protein, carbohydrates, fibre, omega 3 fats or key vitamins and minerals (USDA, 2014; Jakše & Jakše, 2018), giving credible science little chance to prove popular and often unfounded health benefits in a well-designed study (Jakše and Jakše, 2018).
1.10. A black cat crossing your path means bad luck. (Criteria: Testing)
This claim is very similar to the 2.4. argument that has already been explained.

Note: Claims for the first test had number 1 as a leading number and those for the second test had 2 as a leading number. For each claim, the authors used criteria defined in Table 1.

5 Results with Discussion

The results of the case study and the analysis of the data processed by discussion are presented below.

Firstly, the authors wanted to establish whether there was a statistically significant difference between the eighth- and ninth-graders in the performance of responding to the claims raised. The results are given in *Table 4*.

Table 4 shows that students in the ninth grade (80.4%) were somewhat more successful than eighth-grade students (76.2%) in completing the test, which can be explained by longer education in the field of natural sciences.

Table 4: The number (f) and structural percentage of correct and incorrect answers given by the eighth- and ninth-grade students in the first and second tests together

			Answers on Test 1 and Test 2		**Total**
			Correct	Incorrect	
Grade	**Eighth grade**	Number	259	81	340
		Structural percentage (%)	76.2	23.8	100
	Ninth grade	Number	225	55	280
		Structural percentage (%)	80.4	19.6	100
Total		Number	484	136	620
		Structural percentage (%)	78.1	21.9	100

In the continuation the effectiveness of the criteria set for the classification of claims were examined. The results were therefore compared before the introduction of the aid criteria and results using the criteria for the classification of claims (see *Table 5*).

Table 5: The number (f) and structural percentages of correct and incorrect answers given by the students according to the claims of the first and second test

			Student answers		
			Correct	Incorrect	**Total**
Test	Test 1	Number	246	64	310
		Structural percentages (%)	79.4	20.6	100
	Test 2	Number	238	72	310
		Structural percentages (%)	76.8	23.2	100
Total		Number	484	136	620
		Structural percentages (%)	78.1	21.9	100

Table 5 shows that the students were somewhat more successful in completing the first worksheet (79.4%) than the second (76.8%). The results were surprising, since the authors had expected a significant difference or better results on the second worksheet compared to the first one. After the first worksheet the authors held a discussion on scientific and non-scientific claims, where they explained the individual criteria using the statements of the first worksheet. The teacher's intervention focused on argumentation, similar to what was explained in *Table 2* and *Table 3*, using the criteria from *Table 1*. The second worksheet included different statements than in the first worksheet, as the authors wanted to verify the effectiveness of the criteria given in the new cases. Consequently, it is possible that the claims in the second worksheet were more complex for students even though they understood the criteria.

By analysing the results of individual students, the authors realized that 61% of the participants correctly identified at least three quarters of the claims on both tests combined. A comparison between the first and second tests shows that the proportion of those who correctly identified at least three quarters of the claims decreased, as this proportion was 71% for the first test and only 58% for the second test.

For this reason, the authors decided to further check the difficulty index of individual claims. Most of the claims were found appropriate, given that the difficulty indexes were in the 20–80% range (Čagran & Bratina, 2018). Six statements in both worksheets were easier for students, with a difficulty index of more than 80%.

The claims to which all students answered correctly are as follows: *I'll be rich when I grow up; The Sun heats the Earth's surface unevenly, as this depends on the angle at which the Sun's rays are glancing* and *Green plants cannot survive in eternal darkness.* The last two statements refer to the objective set out in the curriculum. In the science and technique class in fifth grade, the students must learn: "that the floor warms up the most when the Sun's rays are at the right angle" (Curriculum. Elementary school program. Science and technology, 2011). They teach the children about photosynthesis in the fifth and sixth grades, where the students have to: "realise that light energy during photosynthesis is converted into energy bound in organic matter (sugar); plants use organic matter as a source of energy and as a raw material for building their own body (e.g., cellulose, starch)" (Curriculum. Elementary school program. Natural science, 2011). According to the results, the students understood why these claims belong to science, as they thought that they had already learned about this in science class.

In addition to the above, there is another claim that most of the students answered correctly. It reads: *If the food is stored in the refrigerator instead of at room temperature, it will deteriorate at a slower rate.* There is no goal in the science or chemistry curriculum that can be linked to this claim, but it is true that understanding the proper storage of food and the functioning of microorganisms is an important topic in home economics class. As many as 26 students (83.9%) from the eighth and ninth grades answered correctly. When asked why they thought the claim was scientific, there was no answer. Only a few sub-questions about microorganisms and their operation at various temperatures led them to a reasoned correct conclusion. A similar picture was observed in a claim on the second worksheet: *Storing hot food in a refrigerator destroys food.* As many as 21 students replied incorrectly; the remaining 10 that answered correctly were not able to explain why the claim was not scientific.

The interviews with students led to the finding that they were very quick to become convinced and believe their teacher too blindly or want to satisfy the teacher and the teacher's expectations. This was also found by Thompson and Logue (2006) in their study, which highlighted the difference between students of different ages. In their explanation, the teacher must use correct professional terms and demonstrate understanding as they transfer the knowledge to students and, consequently, to coming generations (Akgün, 2009).

To perform a χ^2-test, the students' grades in chemistry class were pooled: 2 (sufficient), 3 (good), 4 (very good), and 5 (excellent) and compared them with each other. The authors wanted to determine whether the final grade in chemistry class affected their effectiveness in separation between scientific and non-scientific claims. The results are presented in *Table 6*.

Table 6: The number (f) and structural percentages of the students' correct and incorrect answers to the claims of the first and second test, according to the final grade in chemistry class and the outcome of the χ^2-test

			Student answers on Test 1 and Test 2		**Total**
			Correct	Incorrect	
Grade	Excellent (5) and very good (4)	Number	337	83	420
		Structural percentages (%)	80.2	19.8	100
	Good (3) and sufficient (2)	Number	148	52	200
		Structural percentages (%)	74	26	100

$\chi^2 = 3{,}09$ P = 0,079

The result of the χ^2 -test ($\chi^2 = 3{,}09$; P = .079) shows that the sample was dependent in terms of correct responses according to the final grade in chemistry class, as the error was less than 10%. *Table 6* shows that the students with grades 4 and 5 (80.2%) were slightly more successful than students with grades 2 and 3 (74%). Since the sample was small, the results cannot be generalised to the hypothetical population. Furthermore, some claims related to knowledge of physics and natural sciences and grades in these classes should also be included.

6 Conclusion

From a didactic point of view, knowledge is defined as a system – a logical overview of objective reality, which an individual acquires and permanently retains in their consciousness (Peklaj et al., 2009). Natural science knowledge includes understanding basic facts, concepts, and theories (Štraus et al., 2016). In doing so, students acquire competences that define how well they:

- "Identify natural-scientific questions,
- Scientifically interpret the phenomena and
- Use data from natural sciences and verified facts" (Repež et al., 2006).

Since this is very important in a student's education process, the study sought to examine how students distinguish between scientific and non-scientific claims and whether the use of criteria published by the University Corporation for Atmospheric Research (2015) is effective in understanding science.

The results of the study showed that the use of criteria was not effective, which was surprising, since the criteria were expected to bring science and its understanding closer to students in an easier, simpler way. However, this is clearly not as easy as it seems at first glance. Each student comes from a slightly different environment. The findings of TIMSS 2011 (Kozina et al., 2012), for example, were that students who had a computer, their own desk, and more books at home, achieved better results in science. Better results were also achieved in students whose parents had a higher level of education. The students thus came to school with prior knowledge, which only needed to be upgraded through education (Thompson & Logue, 2006). The problem is that various deficient and incorrect concepts they acquire in early childhood are retained during education. With the acquisition of new knowledge, the old does not automatically overlap with the new, which leads to misconceptions that are very difficult to change or correct (Peklaj et al., 2009). The authors believe that this is also the reason why the given criteria were not as effective as expected. The longer a misconception remains unchanged, the more it takes to root out and the harder it is to change. The question, however, is whether it is in the power of the teacher to eliminate it. The authors believe that the role of the teacher is invaluable in this as well, but one school hour of a planned learning process is certainly not enough for such complex goals. The teacher must first identify the student's misconceptions, only then can they build on eliminating them (Gooding & Metz, 2011).

As Novak and Treagust (2022) describe (mentioned in the 5th chapter of this article), students need many opportunities to make claims based on existing evidence, as well as discussion to use scientific ideas to justify why the evidence supports the claim. They also need support on how to incorporate those scientific ideas into practice. There may also be some difficulty if previous school teachers' ideas surrounding science and their misunderstanding transfer over to the younger generations (Akgün, 2009; Arias & Davis, 2017; Cobern at al., 2022). Connections between a student's misunderstanding of the nature of science and their teacher's understanding were not explored in this study.

In our teaching practice, we need a framework that allows students to develop their understanding over time, as pointed out also by Novak and Treagust (2022). As with any new endeavour, students need multiple experiences – not just one attempt – that allow them to develop an understanding of the practices and relationships among different scientific ideas.

The authors believe that the claims and criteria used in this study are an excellent start to the process of recognising science, as they identified many student misconceptions and explanations during the study, especially in discussions about justifying students' decisions about why, in their view, a claim was or was not scientific.

Based on the results, the authors cannot claim that with these criteria students will fully understand and distinguish between scientific and non-scientific, as there are several factors in the background that influence this. However, it can be said that the results of this study are important, that addressing the topic is necessary, and that this study represents an example of the beginning of confrontation between students and teachers in this field. We are also a step closer to better understanding the nature of science and raising science literacy among Slovenian students in the long run.

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