STE(A)M IT INTEGRATED LESSON PLAN TEMPLATE

Title

Metals and alloys - from ancient past to the future

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Summary

From ancient history up to our days and further into the future, metals and their alloys have had and will have an important role in technological development of civilization as well as in everyday life. Alloys are created in order to enhance specific properties and characteristics of a given material. Today, most commonly used metals are not pure; rather, they are alloys. To see how different alloys have many interesting applications, students will answer the questions and then watch a short NASA video. They will be introduced to the ideas of using for example Nitinol in everyday life in the future (e.g. in healthcare, vehicles, security, construction etc.).

Furthermore, since most problems in construction (machines, buildings, vehicles, cell phones, implants etc.) involve the selection of materials, it is important for scientists and engineers to study materials properties in order to understand and sometimes redesign the structure of a given substance. So students will learn about structure and some chemical, physical and mechanical characteristic of metals/alloys by conducting simple experiments.
At the end of the lessons, they will make items from various materials (metal and alloy wires, plates, screws, …) paying attention to different properties of each material.

Licenses

Subject (s)

Chemistry

Students will investigate structure and chemical properties of metals/alloys.

Physics

Students will investigate physical properties of metals/alloys.

Technical Education

Students will investigate mechanical properties of metals/alloys.

Art

Students will express their creativity in handwork.

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Real- life questions

Which properties of metals/alloys make them so widespread as materials in construction objects of various usages?

How could we improve our everyday life using new alloys?

Aims of the lesson

By the end of the lesson, students should be able to:

Chemistry

• describe some chemical properties of metals/alloys

• compare chemical properties of different metals/alloys

Physics

• describe some physical properties of metals/alloys

• compare physical properties of different metals/alloys

Technology education

• describe some mechanical properties of metals/alloys

• compare mechanical properties of different metals/alloys

Art

• make an item from different metal/alloy pieces (wires, plates, …)

Integrated:

Explain why different metals/alloys have different usage and connection with theirs chemical, physical and mechanical properties.
Develop practical, social and other skills important in everyday life.

Connection to STEM careers

By learning about different metals/alloys students will be able to understand how materials can be used in technology development and how engineers implement those materials:

- material scientists/engineers
- mechanical engineers
- building engineers
- implant end prosthesis designer

By conducting experiments students will get to know about lab researching jobs:

- chemist
- physicist

Age of students

13-14

Time

Preparation time:

• 2 hours to discuss with colleagues and define activities

• 2 hours for each teacher to prepare materials for lessons

Teaching time:

- **Brainstorming and discussion** – 45 min
- **STEM Subjects:** Chemistry, Physics , Technology education – each 90 min
- **non-STEM Subject:** Art – 45 min

Teaching resources (material & online tools)

Materials:

- for models, experiments and handwork (listed in Annex 3.)

Online tools:

https://wizer.me/

https://Padlet

https://kahoot.com/

videos – listed in lesson plan

21st century skills

This lesson plan will enhance among the students the following skills, defined as 21st century skills:

• Critical thinking – analysing the data collected during the experiments, reflecting on the results and making conclusion

• Problem solving – coming up with various experiments to investigate properties of alloys, how to use different types of alloys, why use specific material, environmental issue regarding exploration of metals; breaking down complex problems into smaller parts and working towards their solution

• Creativity and productivity – making various items from alloys

• Innovation – thinking of how to use new alloys in new innovations

• Communication and collaboration – during the group experiments and group presentation

• Information literacy – finding information on internet, using different apps (quizzes)

Lesson Plan

The implementation of integrated STEM teaching and learning is facilitated by the use of specific pedagogical approaches (PBL, IBL, etc.). In order to facilitate the research done by the teachers and the design of activities by teachers, a selection of such approaches is presented in Annex 1. Maintaining Annex 1 in the Learning Scenario and citing where necessary is mandatory.

<table>
<tr><th>Name of activity</th><th>Procedure</th><th>Time</th></tr>
<tr><th colspan="3">1st Lesson</th></tr>
<tr><td>Brainstorming and discussion</td><td>After initial assessment https://app.wizer.me/learn/FDN2Q1 about type of substances, students are divided into smaller groups and each group answers one of the following questions:
1. Are Olympic medals really made of gold?
2. What makes aluminium leading material in aircraft construction?
3. Mercury is poisonous. How come it was used in dental amalgam fillings?
4. What is INVAR and where is it used?

Annex 2. Possible/suggested websites
The group shares their answers on the Padlet.
One member presents theirs findings in a few sentences.</td><td>10 min
20 min</td></tr>
<tr><td>Discussion and preparation for the next lesson</td><td>After a brief historical introduction about importance of metals and alloys (Copper Age, Bronze Age, Iron Age, ...) students are watching video about using nitinol in NASA:
https://www.youtube.com/watch?v=4LOOTyuLjLU
They discuss about video and give their ideas of nitinol use.</td><td>15 min</td></tr>
<tr><th colspan="3">2nd Lesson</th></tr>
<tr><td>STEM Subjects</td><td>Chemistry</td><td>45 min</td></tr>
<tr><td>Videos, discussion and hypothesis formation

Investigation and conclusions</td><td>Introduction – structure of metals and alloys
https://www.youtube.com/watch?v=KgUmNQD6m5Q
Students prepare a particle models of metal and alloy structure with marbles, table tennis balls or similar materials
Task 1. A particle model of metals and alloys
Required material listed in Annex 3.
Students conduct experiments divided into four “research labs”.
Each lab has lead researcher – communicates with teacher, schedules tasks, reports on the results.
Experiment 1. Chemical properties of metals/alloys</td><td></td></tr>
</table>

Name of activity	Procedure	Time
	Students examine how different metals/alloys react with oxygen, water and acid. Required material listed in Annex 3.	
Learning products	A particle model of metal and alloy, results of experiments. Self assessment rubric (in Annex 3.).	
	3rd Lesson	
STEM subject	Physics	45 min
Discussion, videos	In initial discussion, the teacher discusses with students about physical properties of metals/alloys. Students conduct experiments divided into four “research labs”. Each lab has lead researcher – communicates with teacher, schedules tasks, reports on the results. **Experiment 2. Physical properties of metals/alloys** Students examine density (they measure volume and mass of samples and calculate density), electrical conductivity (by electrical circuit), thermal conductivity (on which metal/alloy wire wax melts faster) and magnetic properties of different metals/alloys. Required material listed in Annex 3.	
Learning products	Results of experiments. Self assessment rubric (in Annex 3.).	
	4th Lesson	
STEM subject	Technology education	45 min
Discussion, videos	In initial discussion, the teacher discusses with students about mechanical properties of metals/alloys. Students conduct experiments divided into four “research labs”. Each lab has lead researcher – communicates with teacher, schedules tasks, reports on the results. **Experiment 3. Mechanical properties of metals/alloys**	

Name of activity	Procedure	Time
	Students examine hardness (by scratching one metal plate with other), toughness (how many times wire can be bended before it cracks) and ductility (staying in same position after it is bended) Required material listed in Annex 3. At the end, students solve Worksheet **Metals and alloys.** Listed in Annex 3.	
Learning products	Results of experiments. Self assessment rubric (in Annex 3.) Solved worksheet **Metals and alloys.**	
5th Lesson		
non-STEM subject	Art	45 min
Discussion, videos	In initial discussion, the teacher discusses with students how different metals/alloys are used in arts, jewellery, industrial design…. Students make various items using plates, wires, screws and other forms of metals/alloys. If they are making jewels they also have to pay attention to possible allergies on metals (e.g. nickel) – connection with biological effect (for example hip or knee replacement implants need to be ductile, resistant to corrosion, strong and biocompatible)	
Learning products	Students handwork made of wires, metal plates, … (e.g. jewels, table lamp, chairs, aircraft or spacecraft models…) Final quiz [Kahoot: Metals and alloys]	

Initial assessment

Students solve quiz https://app.wizer.me/learn/FDN2Q1

- What we already know about types of substances? (pure substances, mixtures, …)
- Which type of substance are metals and which are alloys?

Formative evaluation

- discussing the students answers on Padlet
- analysing the students' results, rubrics for selfassessment and worksheet after they performed the experiments
- peer assessment of handwork

Final assessment

- a final quiz with question related to the topics covered in all the lessons: Kahoot: Metals and alloys

Student feedback

Students found questions very interesting and learned fascinating facts they didn't know before. They are always looking forward to conducting experiments and they have also enjoyed handwork. They were very successful in final quiz.

Teacher feedback

The real-life questions we tried to answer are related to the development of technology and consequently making everyday life easier.
By learning about alloys through different school subjects, we have brought the topic closer to students in an understandable way.
Through cooperation, teachers encourage each other to think creatively. Especially, including art teacher, student found rather unexpected. Integrated teaching is great for both students and teachers.
Some students were more interested in alloy usage, some in conducting experiments and others in artistic work.

Suggestions for further lessons:

https://axil-is.com/five-reasons-why-its-important-to-recycle-metals/

https://www.e-education.psu.edu/matse81/node/2087

Annexes

A thorough and complete list of all the materials used will be asked from all teachers. Those materials will be cited as Annexes and they can be further cited in the learning scenario.

Annex 1.

PEDAGOGICAL TRENDS IN EDUCATION

Disclaimer: Information presented in this document has been previously partially published in the Scientix Newsletter "Pedagogical trends in education", May 2019: http://files.eun.org/scientix/scx3/newsletter/Scientix-Newsletter-May- 19.pdf

Inquiry-based science education

IBSE adopts John Dewey's principle that education begins with curiosity (Savery, 2006), and makes students go through all the steps of scientific research: ask a question, develop a hypothesis, plan how to test this hypothesis, collect data, analyse the results and share it with peers (Pedaste et al. 2015). IBSE is ideal for science education, because it makes teaching more hands-on, and is perfect to learn how scientific research works. Students learn how to formulate questions answerable through experimentation. The teacher has both a facilitator role and an instructor role, making it an in-between method compared to full facilitation in problem-based, and instruction in project-based learning. However, the approach can be gradually made student-directed students can start an IBSE project with a question provided by the teacher, and then can come up with their own questions to transfer what they learned for deeper learning.

IBSE does not only tap into creativity, problem-solving, and critical and analytical thinking. It also sets the stage for learning about how to collect and interpret data (become science and data-literate), and how to do this ethically and reliably. All these are skills of the 21st century, where data is abundantly available in every part of life.

As mentioned in the recent European Schoolnet publication, while inquiry-based science education (IBSE) has been already around in STEM education for decades, there is still much room for improvement in teachers' development and continued dissemination of innovative pedagogical approaches. To highlight the impact of IBSE, its challenges, and the initiatives addressing these, we published the "Teacher Training and IBSE Practice in Europe, A European Schoolnet overview". Research shows that IBSE results in greater interest in Science, and motivation for STEM careers. Another important observation from the publication is that the benefits of IBSE are long-term and maintained, in contrast to the short-term acquisitions of traditional pedagogies that also come with less inclusion of both genders, and less interest in STEM.

One challenge is teacher support: teachers report that they receive little support in implementing IBSE in their classroom. Another challenge to IBSE is standard assessment: PISA tests, as well as end-of-secondary-education exams, are still more focused on recall and repeated-drill exercises, deterring the use of more diverse pedagogies. In order to better integrate inquiry-based methods in school curricula, standardized tests also need to evolve along with traditional pedagogies.

Problem, project and challenge-based learning

Problem-based learning (PBL) is a student-centred multi-disciplinary method that was initially adopted in medical education as a means to put multiple topics in context (Newman, 2003) PBL aims to make students good problem-solvers in the real world: for instance, to put knowledge from multiple disciplines into use, and be able to work with others productively. After all, real-world problems are hardly ever solvable by one single discipline and one single person.

A PBL activity consists of working on an open-ended, even ill-defined question, with no solution provided by the teacher. Students need to work collaboratively and devise a solution to the problem by themselves. The key component is that it is student-centred students are more motivated when they are responsible for the solution to the problem, and when the whole process rests with them (Savery, 2006). Decades of research has established that although students who went through PBL do not necessarily score better on standardized exams, they are definitely better problem-solvers (Strobel & van Barneveld, 2009).

Project-based learning also involves collaborative learning and finding a solution to a problem. However, the process and the end product are more specified from the beginning. Students work on a project for an extended period of time, a project that will produce a solution to a complex question or solve a complicated problem. The role of the teacher is more active here because multiple obstacles are typically encountered in the production of something like a rocket, or a space habitat, and these obstacles mark the moments for the teacher to instruct specific topics.

Finally, with **challenge-based learning (CBL)** (Johnson et al. 2009), students are again asked to develop a solution to a problem. However, they are only provided with a “big idea”, a societal problem that they need to address with a challenge of their choosing (e.g. disinterest in mathematics, low upturn in elections). While the use of technology can be considered optional in other trends, technology needs to be incorporated in every step in CBL. Similar to project-based learning, there is an end product, although this product is determined in the process, not at the beginning. The focus is on the use of ICT in the collection of data and sharing the results.

Design thinking

If IBSE recreates scientific methodology in the classroom, **design thinking (DT)** does the same for design and prototype production. DT helps students develop the skill to identify problems and needs in the society, and entrepreneurship. DT can be implemented within problem or project-based learning the difference is that the problem is identified by students, and the end product is a prototype to solve the problem. The product is tested and refined in multiple iterations. Students go through a cycle of steps: (1) empathize (2) define (3) ideate (4) prototype (5) test.

Blended-learning and the flipped classroom

In a classroom where all students are facing the instructor, each moment there will be students drifting from the topic, even if for thinking deeper about a specific point in the lecture. It is challenging to have the undivided attention of the whole classroom because each student has a different way of learning and a different pace. With online content, students can learn the material at home at their own pace. In turn, the teacher can use the classroom to engage students in debates, projects and group assignments. Blended-learning and flipped classroom are instructional strategies that help students learn in their own pace, and deepen their learning with making the most of classroom hours. Although these concepts are used interchangeably, they are slightly different: while blended learning complements online learning with class instruction and support, the flipped classroom requires students to learn the material before coming to class and do assignments and projects during class hours.

Content and Language Integrated Learning (CLIL)

Content and language integrated learning (CLIL) is a well-positioned pedagogical approach that emphasises on the integration of foreign language and thematic content within the context of all school subjects. CLIL is a pedagogical approach that allows to teachers and students use a foreign language as the medium of instruction in non-linguistic subjects, allowing this way the practice and improvement of both the second language and the immersion to subjects that may vary from science subjects to humanities. According to Cenoz et al. (2013) "*the European Commission and the Council of Europe have fundedmany initiatives in support of CLIL because it responded to a need in Europefor* *enhancing second-language (L2) education and bilingualism that was well-received*"and research further supports that CLIL is applied successfully in task-based pedagogies. In addition, when it comes specifically to the application of CLIL in the science classroom there are specific advantages including enabling learners to learn a school subject that exists in their curriculum using the respective second language they are learning, provide authentic learning settings while using the resources available at their school and support learners' cognitive skills by equally supporting language practice and the teaching of science context.

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Annex 2.

Possible/suggested websites:

1. Are Olympic medals really made of gold?
   https://www.compoundchem.com/2016/08/15/olympic-medals/
   https://en.wikipedia.org/wiki/Olympic_medal
2. What makes aluminium leading material in aircraft construction?
   https://www.experimentalaircraft.info/articles/aircraft-aluminum.php
   https://www.flight-mechanic.com/aluminum-alloys/
5. Mercury is poisonous. How come it is was used in dental amalgam fillings?
   https://www.thoughtco.com/amalgam-definition-4142083
6. What is INVAR and where is it used?
   https://www.britannica.com/technology/Invar
   https://www.nickel-alloys.net/article/invar-nickel-iron-alloy.html
   https://en.wikipedia.org/wiki/Invar

Annex 3.

Task 1. A particle model of metals and alloys

Materials:

- some kind of balls in two colures (marbles, table tennis balls ....)
- framework

https://www.youtube.com/watch?v=KgUmNQD6m5Q

Experiment 1. Chemical properties of alloys

Remark: Different samples can be used, depend on which metals/alloys can we get.

a) **reaction with oxygen**

Materials:

- samples of alloys (pieces of bronze, brass, steel, aluminium alloy ….)
- lab burner
- long tweezers

b) **reaction with acids**

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy ….)
- test tubes
- test tube holder
- dill. hydrochloric acid

c) **reaction with water**

- set one week before so potential corrosion can be observed

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy ….)
- test tubes
- test tube holder
- water

Table 1. Some chemical properties of metal/alloy samples

	bronze	**brass**	**steel**	**aluminium alloy**	**…**	**…**
Reaction with oxygen						
reaction with acids						
reaction with water						

Experiment 2. Physical properties of alloys

a) **density**

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy ....)
- graduated cylinder
- scale
- water
- calculator

b) **electrical conductivity**

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy....)
- 4.5 V battery, light bulb, switch, conductors

c) **thermal conductivity**

Materials:

- wires of alloys (bronze, brass, steel, aluminium alloy....) of same diameter (e.g. 0,8 mm)
- candle wax
- lab burner
- stand with ring

d) **magnetic properties**

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy....)
- magnet

Table 2. Some physical properties of metal/alloy samples

	bronze	brass	steel	aluminium alloy	...	...
density						
electrical conductivity						
thermal conductivity						
magnetic properties						

Experiment 3. Mechanical properties of alloys

a) **hardness**

– scratching one metal plate with other

Materials:

- samples of alloys (bronze, brass, steel, aluminium alloy….) – plates 5 cm*5cm

b) **toughness**
– how many times wire can be bended before it cracks

Materials:

- samples of alloys (copper, zinc, bronze, brass, steel, ….) – wires of same diameter

c) **ductility**

– staying in same position after it is bended

Materials:

- pieces of alloys (copper, zinc, bronze, brass, steel, ….) of same size

Table 3. Some mechanical properties of metal/alloy samples (compared with other samples)

	broze	brass	steel	aluminium alloy	…	…
hardness						
toughness						
ductility						

Worksheet: Metals and alloys

Based on experimental results and on what you saw in videos answer following questions.

1. Why is steel better choice than iron?

____

2. Which properties of aluminium and aluminium alloys are crucial for aircraft construction?

____

3. Which metal/alloy has the highest specific strength? Based on data from the table and experimental data, calculate specific strength of samples. Specific strength is calculated by dividing UTS and density. Which metal/alloy has the highest specific strength?

____

Sample	UTS (MPa)	Density (kg/m3)	Specific strength (Pa/kg/m3))
Aluminium alloy	310		
Copper	220		
Brass	500		
Iron	350		
Steel	586		

Source: https://hr.wikipedia.org/wiki/Vla%C4%8Dna_%C4%8Dvrsto%C4%87a

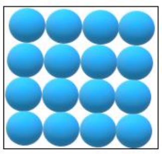
4. Metals and alloys are very good electrical conductors. Why is copper alloy used in electrical wires? What other factors influence metals/alloys usage?

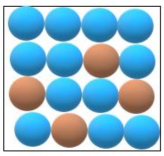
____

5. Which alloy, mentioned earlier in lesson, would you use for e.g. arm implants and which would you use for meteorological instruments? Explain your choice.

____

6. Which one of these particle models represents structure of a metal and which one represents structure of an alloy structure?





Self assessement rubric for teamwork

	+	-	+/-
I listen others very carefuly.			
I respect others opinion.			
I talk calm and kindly.			
I participate in teamwork.			