A New Teaching Approach to The Periodic System

Authors: Annette Lykknes, Rolf Jonas Persson, Per-Odd Eggen, Festo Kayima and Unni Eikeseth, Norwegian University of Science and Technology.

STEMkey
Teaching standard STEM topics with a key competence approach

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Norwegian University of Science and Technology

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International Centre for STEM Education

The aim of this project is to develop an innovative teaching module on the periodic system for Initial Teacher Education (ITE). By generating curiosity-driven, contextualized teaching, we hope to motivate students to in-depth learning in chemistry, and to see the connection between chemistry and other STEM subjects. The target groups are future science/chemistry teachers and HE staff teaching integrated science and/or chemistry didactics in teacher education. The module and its materials might also transfer to in-service teachers as well as to teachers in lower and upper secondary school.

SORTING AND SYSTEMATIZATION OF ELEMENTS

Students feeling the weight of metal discs. Foto: NTNU

Activity: What do you know about the density of the following metals: iron (Fe), aluminium (Al), copper (Cu), titanium (Ti)? Think and discuss in small groups.

- Feel the weight of the different metal discs and order them by increasing weight.
- How does this order relate to the order of the elements in the Periodic Table?

Historical introduction to systematization activities

- In the 19th century, (atomic) weight became the most important characteristic of an element. These atomic weights, that continued to be revised all through the 19th century, became central in the sorting of matter in the same century.
- Meticulous chemical analyses required special expertise

John Dalton:

- There are as many different atoms as there are elements.
- Each kind of atom is characterized by its atomic weight

Playing with numbers and chemical properties: Grouping of elements into triads

- 1817: Johann Wolfgang Döbereiner was the first to discover groups of three elements (triads) which showed chemical and numerical relationships
- At first, he found a relationship between oxides of calcium, barium and strontium:
- The weight of strontium oxide (strontia) was approximately the mean of the weights of calcium oxide (kalk) and barium oxide (baria): (27.5 + 72.5)/2 = 50
- Other triads that Döbereiner identified:
  - (Cl+I)/2 = Br
  - (Li + K)/2 = Na
  - (S- Te) = Se

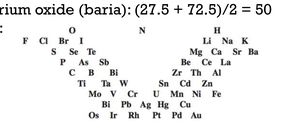


Table of elements based on triads, Leopold Gmelin, 1843.

Activity: Compare the four triads of Döbereiner using today's atomic masses. Do you see the same pattern?

Periodic systems were developed independently in the 1860s by six co-developers:

- John Alexander Newlands (British)
- William Odling (British)
- Alexandre Béguyer de Chancourtois (French)
- Gustavus Detlef Hinrichs (American)
- Julias Lothar Meyer (German)
- Dmitri Mendeleev (Russian)

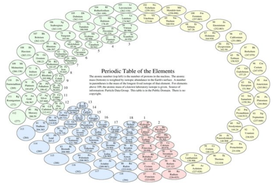
The transition from a system based on empirical observations to a system explained by atomic science

With the discovery of radioactivity at the turn of the 20th century, several radioactive substances which showed similar chemical properties were found to have different atomic weights. At first chemists thought all of these "radioelements" were newly discovered elements.

- In 1913, Frederick Soddy suggested some of them were variants of existing chemical elements, and named these varieties "isotopes" (meaning "the same box" (in the periodic system) - a name suggested to Soddy by Margaret Todd)
- At about the same time, scientists started discovering subatomic particles (1897-electron, 1919-proton, 1934- neutron). Isotopes came to be understood as atoms of elements with identical proton number, but different number of neutrons
- In 1913, Henry Moseley, discovered a relation between an atom's X-ray spectrum and its proton number, i.e., the atomic number.
- The atomic number was accepted as the defining characteristic of an element from ca. 1922 on and replaced atomic weight as the organizing principle for the periodic system.
- In the 1920s, the periodic system was reinterpreted and explained by means of quantum mechanics. Until then, the system had been based on empirical data; now it was explained by science.

- **Activity: Which representation of the periodic system display the periodic law more efficiently?**
- Discuss what can be the benefit of a circle or a helix vs. a table, 2D vs. 3D.

Foto: NTNU



GETTING TO KNOW THE ELEMENTS

To encourage a more positive attitude towards chemistry and to help students give meaning to activities and concepts in chemistry context-based approaches have been developed.

- Context-based chemistry education aims to improve student motivation and interest in chemistry by connecting chemistry concepts with context from the real world.
- The perception of relevance is of special importance for students' motivation and interest e.g. by highlighting chemistry applied in daily-life products and processes and in societal debates about topics like climate change.
- One way of making the elements relevant for students is to ask them to reflect on which elements build the human body.

Activity: Elements in your body

- The illustration shows the average mass ratio of the element s in the human body.
- Which elements do you think are represented by the colour s? Think and discuss in small groups.

The colours on the mannequin represent mass per cent of various elements in the body.

Answer: White= H, Red = O, Black = C, Blue = N, Dark Green (left foot) = Calsium, Orange (right foot)=P, Yellow (finger)= S, Light Green (finger) = Cl, Purple (fingers) = Na + K

UNDERSTANDING SOME TRENDS IN THE PERIODIC TABLE

The Octet Rule is unfortunate as an explanation for why reactions happen.
Often the rule is fulfilled both in the reactants and the products.
In many cases it is not valid, as with sulphur in sulphate.

An example of unfortunate use of the octet rule:

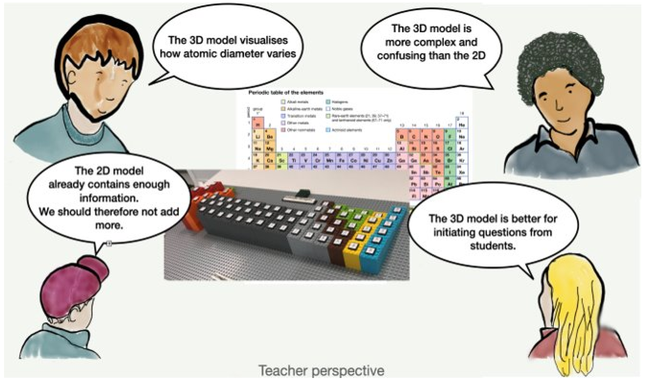
- "Alkali metals want to give off an electron and halogens attract one electron in order to achieve eight electrons in the outer shell" (halogens already have eight electrons as a reactant)

Trends can explain better *why* alkali metals react with halogens:

- Alkali metals easily loose the outer electron due to a combination of low effective nucleus charge and large diameter
- Halogens have a high electronegativity due to a combination of small diameter and high effective charge

Teaching trends in the Periodic Table using 3D LEGO-versions

- For understanding the trends of the Periodic Table, 3D versions can be useful.
- They make it easier for students to see how e.g. atomic radius varies with atomic number
- The 3D-models can be built in LEGO or 3D-printed. Students should have access to the models while discussing trends.



Teachers can choose 3D-models for helping students realize trends that are not easily seen by using an ordinary 2D model. Illustration: NTNU, inspired by Concept Cartoons.

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We would love to hear your thoughts on Key Competence Development in STEM Education!
Did we spark your interest in collaboration? For further information, you can contact us anytime:
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International Centre for STEM Education
icse@ph-freiburg.de
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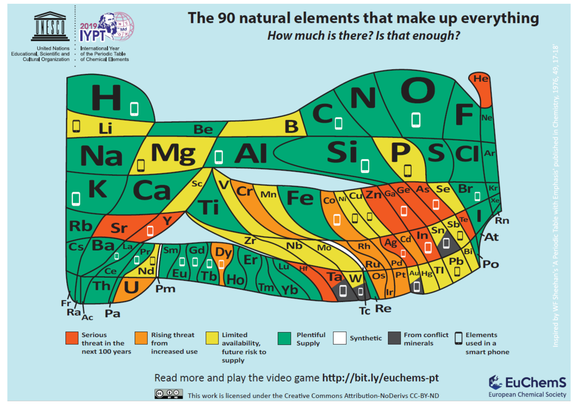
ELEMENTS AND THE SOCIETY



Elements used in different devices come from all over the world. Even if minerals have been found, it is not always possible to mine them. This depends on several factors; Economy, Engineering, Environmental and Ethical factors.
What does this mean?

Activity: Select one element under "rising threat from increased use" and explore and discuss the different uses of the selected element.

- Some of the elements under "rising threat from increased use", have a direct contribution to a clean future. Without a continuous supply of these elements, the world must re-think its global environmental sustainability efforts.
- HOW then how should the question of sustainability be adressed?

REFERENCES

- Bierenstiel, M., & Snow, K. (2019). Periodic Universe: A Teaching Model for Understanding the Periodic Table of the Elements. J. Chem. Educ, 96(7), 1367-1376
- Demircioğlu, H., Dinç, M., & Çalik, M. (2013). The Effect Of Storylines Embedded Within Context-Based Learning Approach On Grade 6 Students' Understanding Of 'physical And Chemical Change' Concepts. Journal of Baltic Science Education, 12(5), 682-691
- Gilbert, J.K. (2006) On the Nature of "Context" in Chemical Education, International Journal of Science Education, 28:9, 957-976, DOI: 10.1080/09500690600702470
- Kaji, M., Kragh, H. & Pallo, G., Eds. (2015) Early Responses to the Periodic System. Oxford: Oxford University Press.
- King, D. (2012) New perspectives on context-based chemistry education:using a dialectical sociocultural approach to view teaching and learning, Studies in Science Education, 48:1, 51-87, DOI: 10.1080/03057267.2012.655037
- Lykknes, A. & Van Tiggelen, B. (2019). Women in their Element: Selected Women's Contribution to the Periodic System. Singapore: World Scientific.
- Osborne, J., Simon, S. & Collins, S. (2003) Attitudes towards science: A review of the literature and its implications, International Journal of Science Education, 25:9, 1049-1079, DOI: 10.1080/0950069032000032199
- Pellegrino, J.W. & Hilton, M.L., Eds. (2012) Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century. National Research Council Division of Behavioural and Social Sciences and Education. Washington, DC: The National Academies Press.
- Salame, I. I., Sarowar, S., Begum, S., & Krauss, D. (2011). Students' alternative conceptions about atomic properties and the periodic table. Chem. Educator 16, 190-194
- Scerri, E. (2007). The Periodic Table: Its Story and Its Significance. Oxford: Oxford University Press.
- Van Spronsen, J. W. (1969). The Periodic System of Chemical Element: A History of the First Hundred Years. Amsterdam, London, New York: Elsevier.
- Sjoberg, S. and Schreiner, C. (2010) The ROSE project An overview and key findings. Retrieved from: https://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf Brock, W. H. (2016). The History of Chemistry: A Very Short Introduction. Oxford: Oxford University Press.
- Ültay, N. & Calik, M. (2012). A Thematic Review into the Effectiveness of Context-Based Chemistry Curricula. Journal of Science Education and Technology 21(6), 686-701