# Material properties and sugar combustion

## Open Educational Resources for inclusive education

Inclusive STEM education poses new challenges for teachers: How can science and technology be taught in a differentiated manner that still serves the needs of the whole class? How can we ensure that all students – irrespective of their need for support or their cultural, linguistic, and socioeconomic background – have an optimal, individualized, and yet shared learning experience? The education policy mandate for inclusion cannot easily be met with conventional teaching materials. Ideas and assistance, specifically for teachers in the fields of science and chemistry, can be found in the inclusive experimentation units developed by the Siemens Stiftung in cooperation with its partners, the iMINT-Akademie (Inclusive STEM Academy) of the Department of Education, Youth, and Family in Berlin and the State Institute for Educational Quality and Teacher Training (LISA) in Saxony-Anhalt.

### About the Media Portal of Siemens Stiftung

The Media Portal of Siemens Stiftung offers some 5,500 teaching and learning materials – content packages for interactive whiteboards, videos or experimentation instructions that enable a diverse STEM classroom experience. Some 3,500 media are available as Open Educational Resources (OER). They can be downloaded at https://mediaportal.siemens-stiftung.org and freely modified, shared, and republished. All the media are curriculum-oriented and available for free download in English, German, and Spanish.

The teaching and learning materials are based in part on the Siemens Stiftung's international educational program "Experimento" and on the standards for experimentation in the inclusive education of the iMINT-Akademie. Above all, the diversity- and community-oriented approach helps students develop values related to the learning process such as team spirit, tolerance, and a sense of responsibility – values that can be put into practice right there in the classroom.

## Inclusion as an educational mandate

Providing optimal support for all students according to their unique abilities is above all a didactic challenge. Prominent researchers agree that hands-on, research- and development-driven instruction that addresses the interests of all students and taps into their experiences is one way to improve shared learning. Above all, students should have the opportunity to bring their prior knowledge and skills into the classroom. Discovery-based teaching offers the ideal conditions for this.

"Material properties – a research expedition" is a learning module inspired by experimentation ideas in the Experimento | 8+ project of the Siemens Stiftung and developed by a teacher group at the iMINT-Akademie for inclusive science teaching in grades 5 and 6.

"We burn sugar" is a learning module for grades 10 and up, based on a media package of the Experimento | 10+ project, is another good example. This media package was revised and expanded for greater inclusion by a teacher group at the State Institute for Educational Quality and Teacher Training in Saxony-Anhalt.

Both learning modules are available for download as *Open Educational Resources* (OER) from the Media Portal of Siemens Stiftung and the educational servers of Berlin-Brandenburg and Saxony-Anhalt (→http://www.mediaportal.siemens-stiftung.org).

## Research expedition instead of following directions

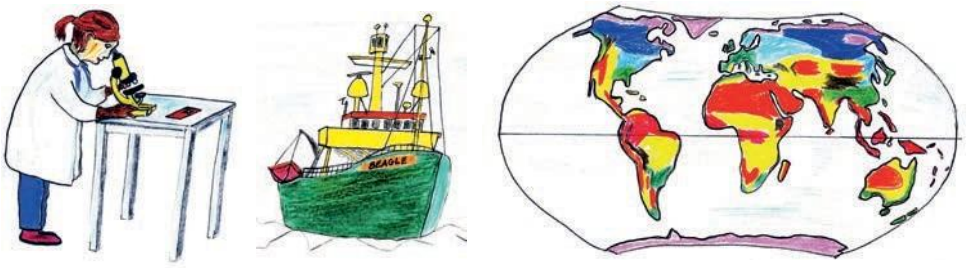
Nothing happens without motivation. Learning through independent research and activity is the secret to effective, inclusive education. A motivating learning environment is critical for the more learning-challenged students in particular. That's why the "material properties" learning module, which is divided into three learning environments, has a narrative about the fictitious oceanographer Prof. Cousteau setting out for a trip around the world in her research ship "Beagle." This narrative draws in the students from the beginning: At the start of each learning environment, she asks the students by email to help her sort materials (learning environment 1), conduct experiments on the materials (learning environment 2), and determine the properties of materials (learning environment 3). Students are also engaged through the request to bring as many different materials as possible to class (T-shirt, string, paper clips, nails, a glass marble, Lego pieces, yogurt cups, kitchen foil, etc.). They see the research expedition as their own project. (see **Fig. 1**)

## Turning student diversity into an asset

The teacher acts as organizer, guide, and consultant for this learning module, encouraging the students to find individual, creative, and above all independently chosen solutions.

– Learning environment 1 has students first working together on the same assignment with a low barrier to entry.
– Learning environment 2 has detailed partial assignments at a differentiated level of understanding and abstraction. Each task of varying difficulty is assigned to a group with a uniform skill level. This accommodates individual working and learning paces and allows all students to participate in the solutions according to their abilities.
– Learning environment 3, on the other hand, turns to groups of mixed skill levels to allow students to support one another on complex assignments.
– The students themselves decide which tools to use and how to document their work. The focus is on the unique solution they find.
– The only way to complete the assignments is through a common dialog through the various processing channels. This way, the students reflect on their individual solution strategies and gain a better understanding of the material.

The learning module also offers ideas for extra assignments to push the students who finish more quickly than the others. Successful collaboration between stronger and weaker students generally shows that it is not only the weaker students who benefit. What any student learning group knows also plays out at the school: Explaining something to others reinforces your own knowledge!



**1 |** Students support the research expedition of oceanographer Prof. Cousteau

| Incremental hints |
|---|
| Place the answer card in the second envelope: |
| **Heat – hint card 2:** |
| To investigate thermal conductivity, you will **not need** the following:<br>- Magnet<br>- Battery<br>- Incandescent lamp<br>- Table salt<br>- Cable |
| Place the answer card in the third envelope: |
| TIP **Heat – hint card 3:**<br>Think about the materials you need for your experiment. |

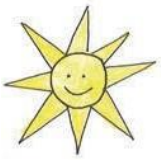
**3 |** Incremental hints to help students with problem-solving

**Word list of objects**

| Pictures of objects | Name | Pictures of objects | Name |
|---|---|---|---|
|  | Foil (aluminum) |  | Sticks (wood) |
|  | Cloth (cotton) |  | Nails (iron) |
|  | Paper clips (iron) |  | Wire (copper) |

**2 |** Word lists to help students work with many different materials

**Learn about other properties of the materials**

| | Material properties | |
|---|---|---|
| |  |  |
| Materials: | **Melting temperature:** The material … melts at …°C | **Boiling temperature:** The material … boils at …°C |
| Iron | 1,538 | 2,862 |
| Copper | 1,084 | 2,567 |
| Aluminum | 660 | 2,467 |
| Table salt | 801 | 1,413 |
| PP | 100 to 110 | None |
| PET | > 250 | None |
| Glass | Between 600 and 800 | None |
| Cotton | No melting point | No boiling point |

**4|** Data cards to be filled out by the students themselves

## Promoting language skills with visual aids

Recording what you've learned, designing posters, and explaining course content in brief presentations: All of this is part of the modern classroom experience. "Problem cards" instruct the students to gather information, articulate questions, form an opinion about the subject matter, and develop and defend hypotheses. All these tasks also help encourage and develop linguistic skills.

A range of visual hints assist students who have difficulties in this area. A word list, for example – in an easy-to-use two-column format (see **Fig. 2**) – helps them deal with the many different materials and use the correct vocabulary in their discussions. The problem cards and hint cards also use small icons for each problem. For help with the posters and presentations, a worksheet provides visual elements (icons for the material properties, etc.) and linguistic tips for talking about scientific subjects.

## Approaching advanced content through incremental assignments

The difficulty in learning through independent research and activity is more than just linguistic, however. Understanding the advanced subject matter requires a considerable capacity for analysis and abstract thinking that could initially overwhelm some students. Such students can become quickly discouraged, feel they're in over their heads, and then contribute less or withdraw completely. The learning module uses "hint cards" to help prevent this scenario from occurring. They are not mandatory but can be used by the students if they're stuck. The incremental hints, based on a concept by L. Stäudel, encourage independent learning by offering students step-by-step support in solving their problem while still allowing them to learn and solve problems in their own way. (see **Fig. 3**).

The answer cards of these incremental hints always have the same format. The first hint card encourages students to formulate the problem once more in the group to gain a clear picture of the problem. Other answer cards provide students with hints for a structured, scientific solution. The last phase can be used by stronger groups who have completed their assignment without any hints to check their solution.

The assignments also require students to research precise material properties such as the melting point of certain substances. The students' experimentation gives them at best only a qualitative picture of these material properties, so they need to conduct research as well. To this end, the learning module offers "data cards" that the students can easily complete on their own. (see **Fig. 4**).

## In short: more than just worksheets

The learning module "Material properties – a research expedition" offers more than just worksheets with instructions for use and directions for recording and analyzing results. It also provides significantly more support for shared discovery-based learning for students with different levels of educational readiness. The author finds it especially effective, especially for the intended age group, that these hints are not a "supplement" to a conventional learning module but fully integrated and "fully inclusive" in their content and educational approach.

## Supplementing existing learning modules for inclusive education

Not all materials always need to be developed from scratch. Existing media can also be adapted for inclusive learning environments, as the module “We burn sugar” for grades 10+ illustrates.

The ability of our cells to burn glucose is essential to human life. That’s why students are typically motivated to conduct their own experiments on the subject of “sugar combustion.” Understanding that a catalyst is needed for sugar to ignite makes it easier to grasp the processes in the human body, where sugar burns at about 36 °C with the help of biocatalysts.

The original learning module contained detailed teacher and student instructions, a detailed information sheet entitled “Sugar combustion and cellular respiration in the human body,” and a list of links. The module has been expanded to include an answer sheet for the calculations assigned in the student instructions and the questions posed there. The graphic “Mitochondrion — a mini power plant,” the content package “Energy metabolism in humans,” and the interactive graphic “Catalysis principle” complete the package.

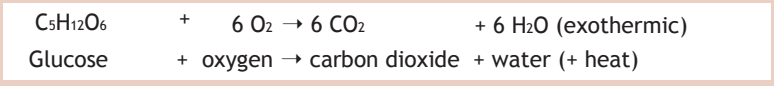
Additional media in the inclusively enhanced learning module accommodate the unique need for assistance:

The somewhat simplified worksheet on catalysts offers a historical overview and definition of the term “catalyst” with related assignments. An extra page in the student instructions outlines a detailed research assignment.

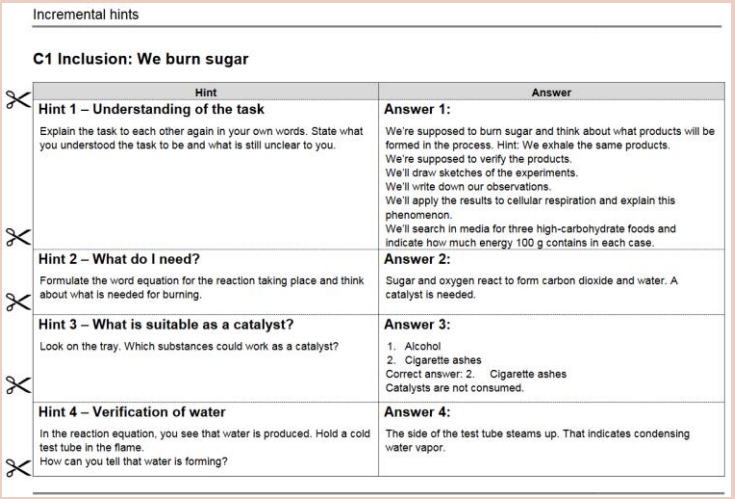
The media are offered as Open Educational Resources (OER), so teachers can adapt or augment them as they see fit. If the students are still a little shaky when it comes to writing chemical equations, for example, teachers can insert word equations into the simplified student instructions (**Fig. 5**).

There is also a separate document with “incremental hints” (**Fig. 6**) so that, if needed, students can complete the assignments without direct help from the teacher. An extra handout augments the teacher instructions for inclusive education.

A lack of language skills is increasingly emerging as a barrier to learning science and technology, even in the upper grade levels. For this reason, the teaching module has been augmented for inclusive learning with two worksheets and the corresponding answer sheets to support language-sensitive science instruction. “Word lists” and “language building blocks” help students learn the right words and technical jargon.




**5 |** Teachers can modify or augment any of the media of the learning module in packages, of course. Here, for example, a word equation complements the chemical equation in the original document.



Incremental hints

**C1 Inclusion: We burn sugar**

| Hint | Answer |
|---|---|
| **Hint 1 – Understanding of the task**<br>Explain the task to each other again in your own words. State what you understood the task to be and what is still unclear to you. | **Answer 1:**<br>We're supposed to burn sugar and think about what products will be formed in the process. Hint: We exhale the same products.<br>We're supposed to verify the products.<br>We'll draw sketches of the experiments.<br>We'll write down our observations.<br>We'll apply the results to cellular respiration and explain this phenomenon.<br>We'll search in media for three high-carbohydrate foods and indicate how much energy 100 g contains in each case. |
| **Hint 2 – What do I need?**<br>Formulate the word equation for the reaction taking place and think about what is needed for burning. | **Answer 2:**<br>Sugar and oxygen react to form carbon dioxide and water. A catalyst is needed. |
| **Hint 3 – What is suitable as a catalyst?**<br>Look on the tray. Which substances could work as a catalyst? | **Answer 3:**<br>1. Alcohol<br>2. Cigarette ashes<br>Correct answer: 2. Cigarette ashes<br>Catalysts are not consumed. |
| **Hint 4 – Verification of water**<br>In the reaction equation, you see that water is produced. Hold a cold test tube in the flame.<br>How can you tell that water is forming? | **Answer 4:**<br>The side of the test tube steams up. That indicates condensing water vapor. |

**6 |** Incremental hints were added to the media package to help students in an inclusive classroom environment complete the research assignment. They were not included in the original version of the media package. Even in the upper grade levels, weaker students can easily lag behind on some steps when working alone. The incremental hints help them keep up with the class here as well.

## It takes a team

The extra time undoubtedly required to prepare and organize inclusive education is enough to make many teachers skeptical. All the more important, then, that they find support in this effort. The freely downloadable Open Educational Resources (OER) presented here are a good solution, since they can be adapted to each teacher’s unique needs, shared with others, and republished.

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