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STEMSiL

STEMSiL Handbook

STEM Teaching and Learning in Sign Languages: Ten Recommendations

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Introduction and Overview

Effectively teaching deaf students STEM requires innovative methods that have been proven to make better use of class time through the targeted integration of sign language. Here are ten innovative teaching methods that can be used to achieve the desired academic outcomes compared to traditional teaching methods with insufficient use of sign languages in STEM classrooms.

The collection of teaching methods presented is not exhaustive, but it is useful for STEM educators as a starting point for understanding the possibilities of theoretically grounded implementation of sign languages in STEM education. The methods show exemplary what could be the first steps and give some ideas for more elaborate teaching of STEM in sign languages.

By experimenting with the suggested teaching methods, teachers can adapt them to the needs of their students and gain some strategies to improve their own language skills and STEM expertise. Let us now look at these ten teaching methods that can be a game changer for many Deaf students in STEM classes, contribute to the development of school practice and build bridges to research.

1) Development and use of STEM syllabus in Sign Languages

STEM curriculum in SL needs to take into account

- Deaf gain and Deaf culture in STEM
- Perceptual asymmetries
- Diversity of linguistic repertoires of deaf learners.

The handbook gives examples to give an idea for further curriculum development in STEM education in sign languages.

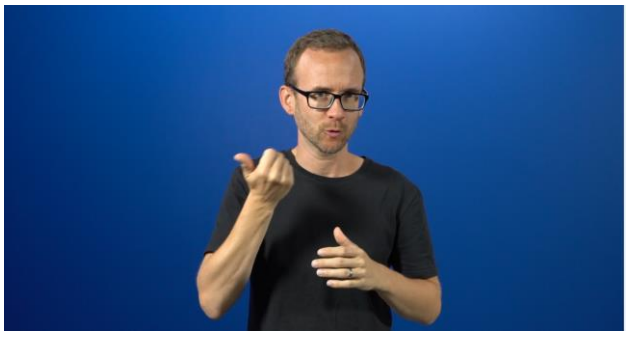
2) Use of video clips starring STEM Deaf experts in sign languages

Video clips featuring STEM Deaf experts

a) provide Deaf role models for students

b) give deaf and hard-of-hearing (DHH) students a better understanding of the benefits and requirements of STEM education and careers,

c) provide sign examples that can be used to expand STEM vocabulary and STEM language use in STEM classes.



3) STEM Concept Cards

STEM Concept Cards can be used to explain selected STEM concepts. The aims are

- to introduce DHH students to different STEM concepts,
- to assist teachers, interpreters and researchers to develop learning materials using STEM vocabulary and STEM vocabulary derived from DHH learners' signs repertoire,
- to help teachers, interpreters and researchers understand how DHH students think and find ways to better communicate STEM knowledge.

4) Adapting of STEM glossaries established by Deaf STEM experts

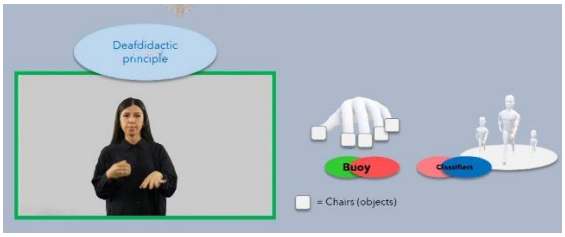
- Explaining concepts in SL
- Adapting to the age, cultural and linguistic background of the learners,
- using examples, illustrations, dynamic animations, 3D models and movements

5) Linguistic and iconic strategies in the expression of STEM concepts

Inspired by sign language research, specific didactics of STEM subjects and deaf didactics, we suggest the use of linguistic and iconic strategies to describe, explain and discuss STEM concepts and provide concrete examples.

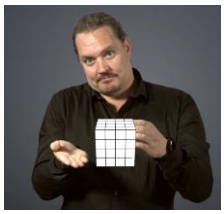
Examples of linguistic and iconic strategies:

- use of **iconic superstructures,**
- creative **use of space,**
- flexible **change between 2D and 3D.**



CR: Competence Center for Sign Language and Gesture *SignGes*

6) Visualizing materials used in the classroom – Use of visual cues



STEM Methodologies in Sign Languages, STEMSiL

DHH students are often considered as visual learners, and the use of visual tools is recommended for deaf education. However, meaningful use of visualization strategies in STEM education requires embedding them in signed, written or spoken explanations (texts, videos) adapted to the individual perceptual situations and linguistic repertoires of DHH learners.

7) Creation of Sign Language video clips explaining selected STEM concepts – Online presentation

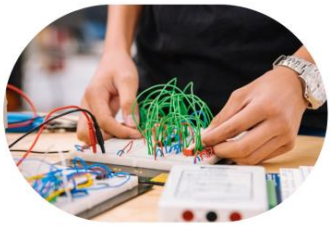
To develop language skills and increase STEM knowledge and competences, DHH students can be asked to create their own videos in their sign language, documenting their own scientific experiments, internet or literature research, reflections, discussion of results, collaboration with their peers and, if possible, STEM Deaf experts outside the school.

8) STEM dialogue in and outside the classroom: Short presentation and discussion

To support dialogue and cooperation between different schools, other educational and research organizations, we suggest implementation of

- STEM competitions,
- STEM slams,
- STEM summer camps

9) Use of co-creation toolkit – with technology tools

	The use of technology can help to connect the teaching of different STEM subjects in sign languages through the use of • programming • Lego creations • robotics • technology to work with materials such as wood, metals, etc.

10) Use of co-creation toolkit – without technology tools

As an alternative to experiments using technology, it is recommended to carry out experiments using handicrafts that require direct contact with nature, materials or each other.

This will give DHH students the opportunity to derive STEM vocabulary, explanations and iconic superstructures in their sign language to describe the experiments directly from the students' actions, the visible and tangible properties of the objects and the core phenomena investigated by the experiments.

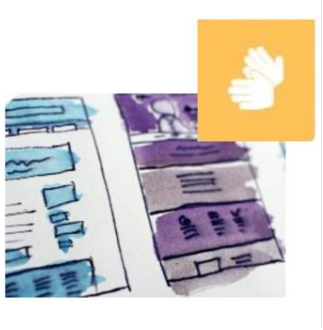
The presented teaching methods are derived from the review of theoretical concepts, experiences of DHH and sign language teachers, suggestions of Deaf STEM experts and deaf researchers. For a deeper insight into the theoretical perspectives and empirical studies as a didactic framework for the suggestions, we recommend the project handbooks. Once teachers and interpreters have tried out our suggestions, they are welcome to provide constructive criticism and suggestions for modifications.

1) Development and Use of Deaf STEM Syllabus in Sign Languages

Teaching DHH students STEM effectively requires innovative methods that have been proven to work effectively through the targeted use of sign language. Here are ten innovative teaching methods that can be used to achieve the desired academic outcomes and make more effective use of class time compared to traditional teaching methods without or with insufficient use of sign language in STEM classrooms. Implementation will take time and effort, but it is worth it and will bear fruit in time.

The collection of teaching methods presented here is not exhaustive, but it is useful for STEM educators (and interpreters) as a starting point to understand what the possibilities are for implementing sign languages in STEM classrooms, what could be the first steps, and gives some ideas for more elaborate teaching of STEM in sign languages. By experimenting with different teaching methods, teachers can adapt them to the needs of their students. Let us look at these ten teaching methods that can be a game changer for many DHH students in STEM classrooms.

Development and Use of STEM Syllabus in Sign Languages



STEM curriculum in SL needs to consider three aspects:

- Deaf Gain and Deaf Culture in STEM
- Perceptual asymmetries,
- Diversity of linguistic repertoires in DHH learners.

The handbook gives examples to give an idea for further curriculum development in sign languages.

The first and most important step in effectively teaching STEM to DHH students is to critically examine the official curriculum regulations and educational standards for STEM subjects, which usually do not take into account the linguistic repertoires and perceptual situations of DHH students.

Usually, STEM curricula are developed by non-signing professionals in STEM education who are not aware of new trends in Deaf and sign language education. However, DHH students are usually expected to achieve the same educational standards without appropriate teaching in their visual-gestural modality.

On the other hand, some subjects such as 3D geometry, which could benefit from visuo-gestural modality, are underrepresented in established curricula due to the limitations of 2D of traditional teaching materials such as books or even newer ones such as dynamic geometry software that use a 2D computer screen.

In order to reflect on the curriculum of particular STEM subjects and to adapt it to DHH learners, you can ask yourself and your deaf colleagues the following questions

- How relevant are the topics suggested by the standard curriculum to the successful lives and careers of individual DHH students?
- What is the relevance of the specific STEM topics to the Deaf / sign language communities?
- What is the relevance of the topics to the STEM community in general?
- What achievements of Deaf STEM experts are underrepresented in specific STEM curricula and need to be added?

- Are there sign language user-friendly materials for target groups of DHH students?
- How can new materials with explanations in sign languages and linking of sign languages to the corresponding words in the text be developed and made available?
- Do bilingual/bimodal learning environments exist?
- Who are the STEM experts to collaborate with to save time in development?

The overall aim of the STEMSiL project is to help you find your own answers and give you some ideas of what can be done to address these issues. It provides examples of teaching materials such as subtitled STEM videos and gives examples of teaching using STEM toolkits in user-friendly language. However, the main and global aim of the project is not to give final answers to all possible questions, but to motivate teachers and educational researchers in STEM fields to ask their own new and critical questions by examining the established STEM curricula of concrete subjects.

We invite every teacher and every researcher to work together with students, parents and other stakeholders for changes in national educational policies by keeping special situation of DHH students on the one hand and Deaf gain on other hand in mind.

In order to achieve change, it is important to become active participants in the development of educational standards, to consider sign languages as an essential part of STEM education in the process of developing educational standards, and not only to find ways to adapt standards or methods when they are already being delivered to schools and other educational institutions.

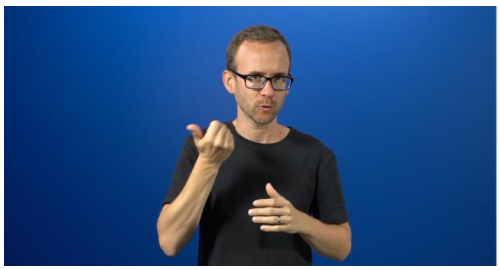
One way of initiating change can be to ask Deaf students and Deaf STEM experts, Deaf STEM teachers, Deaf biologists, Deaf mathematicians, etc. what they consider to be important parts of STEM curricula for Deaf people. This can be done, for example, through co-creation activities using STEM kits and documented as videos produced by Deaf learners themselves.

Cube and cuboid as an example

In the traditional curriculum for grades 5 and 6 in Berlin (Germany), students are expected to use 3D models of cubes and cuboids to describe cubes and cuboids as geometric solids with their properties and relationships between them in words. They should learn to draw two-dimensional sketches and to work with nets of cubes and cuboids. Not only in case of DHH students it could be helpful to document curricular requirements not only as texts or tables but also as videos in sign languages and to describe cubes and cuboids in sign languages. This could help to embed 3D models as parts of the physical world in the scientific description of the concepts and expected competences of the learners in sign languages.

International Sign

2) Use of Video Clips staring STEM Deaf Experts in Sign Languages



Video clips featuring STEM experts

- provide Deaf role models for DHH students
- give DHH students a better understanding of the benefits and requirements of STEM education and careers,
- provide sign language examples that can be used to promote the use of sign languages in STEM classrooms.

In the previous section, we explained why it is important to develop special STEM curricula in sign languages for DHH students and suggested working with Deaf STEM experts to take the first steps. However, the time of Deaf experts is always limited, and unfortunately they cannot be invited to every school. Therefore, it is necessary to use video clips with Deaf STEM experts as teaching materials. Furthermore, video clips provide unique opportunities to empower Deaf learners to start STEM careers and promote their linguistic skills in different modalities (I.e. in sign and written languages) that are perceptible despite perceptual asymmetry.

Empowerment through Deaf STEM role models

In the interviews, Deaf experts discuss about their school experiences and educational biographies, their paths into STEM. They provide insights into the benefits and challenges of STEM education for DHH students. These video clips can help Deaf learners to better understand STEM careers, to choose a particular STEM field, to start looking for strategies to achieve their career goals, to create their own scientific paths and to appreciate networks of Deaf scientists. In this sense, experiences of Deaf STEM experts can empower Deaf learners to start STEM careers.

The opportunity to learn about STEM careers and STEM education from peer to peer is the next potential of using video clips with deaf STEM experts.

Video clips as tools for STEM education in sign languages

The video clips provided by STEMSiL were originally made in national sign languages and have been transcribed and translated into partner countries' sign languages and International Sign Language (IntSL). In addition to empowerment through Deaf role models, video clips with STEM experts provide sign language examples that can foster learning experiences in STEM in sign languages. Video clips can be used to enable Deaf learners to gain a deeper understanding of signed and written texts focused on STEM and to develop their literacy skills in their sign and written languages.

Ways to improve the sign language skills of STEM educators and interpreters

Most STEM educators and some (beginning) sign language interpreters are not proficient or fluent enough in their sign language to understand and to describe scientific concepts. They continue to learn during their professional career as a teacher / an interpreter. In this case, video clips play a crucial compensatory role and can also be used by teachers and interpreters to improve their own language skills, especially in terms of specific STEM vocabulary and perception of complex constructions.

How can we use video clips featuring Deaf STEM experts in the classroom?

Having presented the benefits and learning opportunities of video clips featuring Deaf STEM experts, we would like to give some practical recommendations on how they can be used in the STEM classroom.

Preparation

Start by selecting video clips that are appropriate for the age group and STEM subject. Study several video clips to make suggestions to your DHH students and ask them what interests them and what they would like to see. Watch the chosen video beforehand and note down the main messages of the interview and the key signs used by the Deaf STEM expert. Mark any STEM signs that are new and unfamiliar to you.

Viewing of the video clip in the classroom

Decide whether you want to show the video in the classroom and watch the clip together, or whether you want to allow DHH students to use their personal devices such as mobile phones or tablets. In this case, DHH students could adjust the space and speed to suit their sign language skills. If there is enough time, they can watch the video again and again to understand it better and to take notes. Afterwards, you can watch the video clip together to clarify unfamiliar STEM signs and their accompanying words or to discuss the STEM-related content, stopping at certain points.

Marking of interesting STEM signs, words, expessions and parts of the text

DHH students can mark interesting STEM lexical items and utterances (in form of signs, words, expressions and parts of the text) by documenting parts of the video as frames and commenting on them, inserting pictures into the video, rewriting transcripts or signed passages to make them easier to understand for themselves and their peers.

Reproduction

You can have the DHH students reproduce certain passages or even the whole interview in their own sign language. It will enable them to have an opportunity to work on their language skills. This can be documented in videos.

Text analysis

The student can also be asked to analyze the STEM content or linguistic aspects of the video in more depth to discuss the aspects of being a Deaf STEM expert or learning more about the use of sign and written languages within the STEM context.

Further research

After discussing the video clip, DHH students can search the Internet for additional information about the expert and the STEM field presented in the video clip to deepen their knowledge.

Reflection through time travel

To reflect on aspects of the content and relate it to their own lives, DHH students can be asked to travel through time and imagine themselves in ten years' time in the role of a STEM expert and give their own imaginative interview as a future STEM scientist.

International Sign

3) STEM Concept Cards

STEM Concept Cards can be used to explain selected STEM concepts in SL. The aims are to

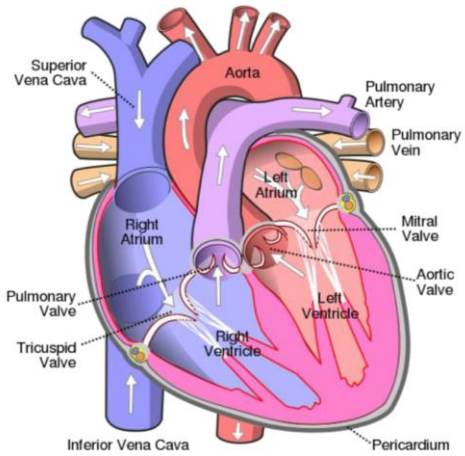
- introduce the DHH students' point of view on different STEM concepts,
- assist teachers, interpreters and researchers to create learning materials using STEM signs utterances signed by DHH learners.
- enable teachers, interpreters and researchers to understand how DHH students think and to find ways for better knowledge transfer.

Design of Concept Cards

To understand the didactic potential of the concept cards, it may be helpful to know more about the design process. First, DHH students learn how to use visualization techniques of STEM phenomena and processes efficiently. They will be asked to explain the concepts behind them. These explanations are not expected to be a perfect description of the scientific concepts but should show what the DHH learners think about the concept and how they express their STEM knowledge.

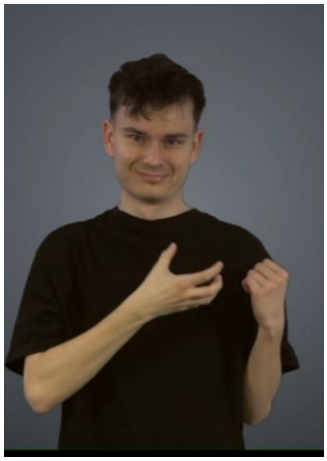
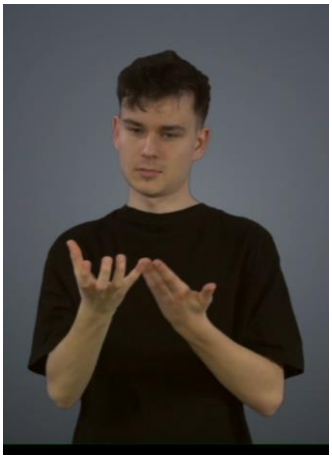
Example from Biology

Given a schematic diagram (see below), DHH learners acted similarly to professional scientists, selecting and creating new signs to describe the human heart. The visuals were embedded in the iconic structure presented in the context of the human body, represented as the body of a young signer. They used the body parts as tangible objects.



https://en.wikipedia.org/wiki/File:Diagram_of_the_human_heart_(cropped).svg

To explain the concept of the HEART, DHH learners carefully considered its location in the body, its shape and its function. To describe the heart, they 'opened' the chest, 'took out' the imaginary heart and 'placed' it in their hand to explain its function and blood flow.

		
location in the body	**approximate size and shape**	**heart “placed” in the hand**

In the description of the function, we can find other important signs from biology, such as blood or oxygen, which may be necessary for explanation. We also have signs derived from schematic representations, such as arrows showing the direction of blood flow.

		
blood	**blood flow into the heart**	**oxygen**

		
blood flow direction	**blood flow direction**	**blood circulation**

How you can use Concept Cards in the classroom?

The first thing to remember is that concept maps are not formal definitions and descriptions of scientific concepts produced by experts. They give an insight into learners' actual understanding of scientific concepts, adapted to the language of the peer group. They are not perfect end points in the description of the concepts, but they can be used as a starting point to reflect on the concepts in the classroom and to derive important STEM vocabulary that is understandable to the students. Therefore, it is necessary to study the concept cards in advance and to examine them from the teacher's point of view.

Introduction of the method by producing own Concept Cards

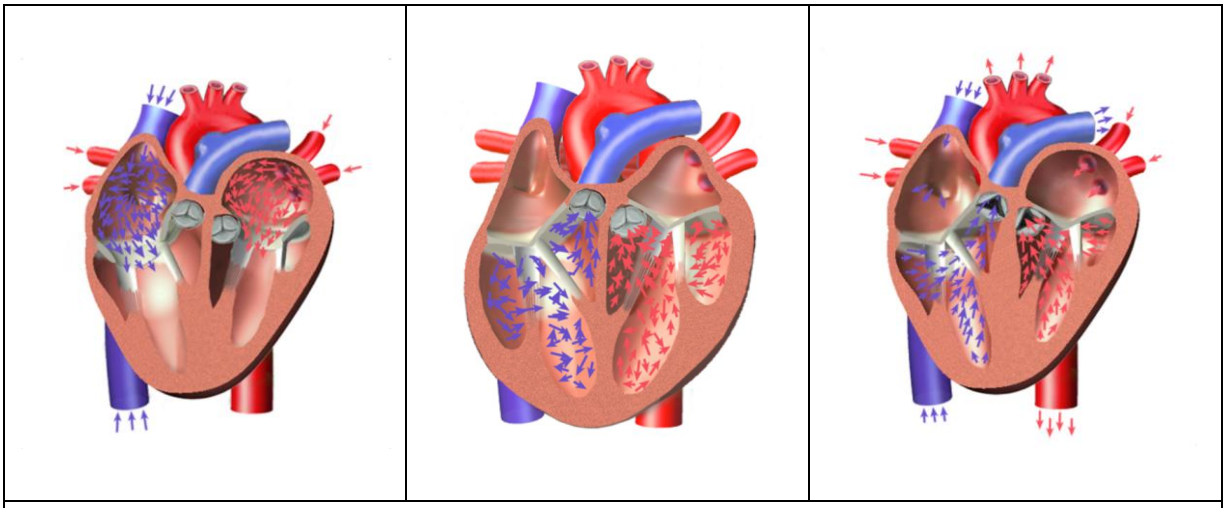
To introduce your students to the method, you can give them the schematic visualization techniques of the concept (just like the schematic visualization of the heart above). Ask DHH learners to discuss the concept in small groups using the visual and allow them to use additional materials. Ask DHH students to make their own concept cards.

Presentation of Concept Cards produced by STEMSiL

Once the students have produced their own concept cards, show them the concept cards produced in the STEMSiL project. You can compare the cards and ask your DHH learners if they could find new information, new STEM vocabulary, new important signs and strategies to describe the concept.

Linking signs, visuals, words and written texts

To gain a better understanding of the process, you can ask your DHH students to link signs and given visuals or even ask them to create their own visuals or animations that correspond more closely to the signs. You can also swap visualizations of different steps to go deeper into the process, use models and link them to videos in SL. Finally, link individual key signs to words if this is possible without changing the meaning (as in the table above). Finally, ask DHH learners to create their own explanations in written language as texts. Allow them to use text examples for guidance.



- Your heart is actually a muscle. It's located just to the left of the centre of your chest and is about the size of your fist. Your heart is like a pump, or two pumps in one. It pumps blood around your body. Blood gives your body the oxygen and nutrients it needs. It also carries away waste products.
- The right side of your heart receives blood from your body and pumps it into your lungs.
- The left side of the heart takes blood from the lungs and pumps it out to the rest of the body.

Source: https://kidshealth.org/en

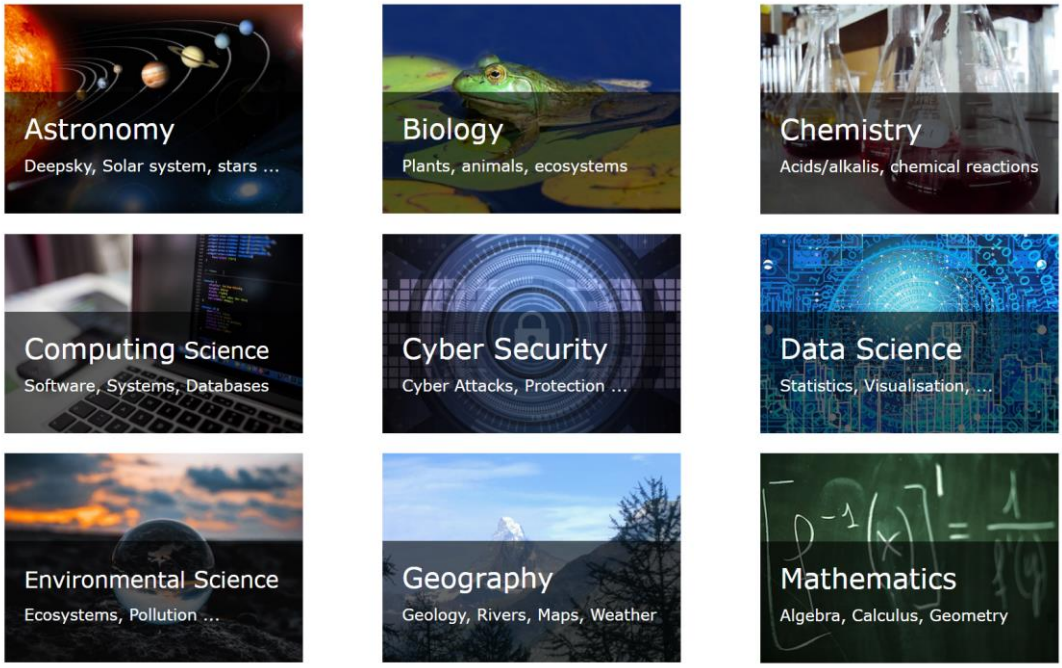
International Sign

4) Adapting of STEM Glossaries

Once students have created their own explanations of concepts and those of their peers, it is important to go further and introduce them to the STEM glossaries developed by Deaf experts such as the BSL Glossary or Sign2MINT with additional materials (animations and videos).

The aims are to

- introduce students to formal explanations of concepts in SL,
- help to adapt them to the age, cultural and linguistic background of the learners,
- to show possibilities of using examples, illustrations, dynamic animation, 3D-models and movements to explain scientific concepts,
- to give a concrete idea how STEM glossaries can be used in teaching sign language as L1 or L2.



BSL Glossary for STEM (without Physics)

Source: https://www.ssc.education.ed.ac.uk/BSL/#mySearch

Linking with Concept Cards

Once the students have expanded their conceptual understanding and linguistic repertoire of a particular concept, such as heart, through the use of Concept Cards, and have documented their new understanding through the videos and texts shown previously, they can try to use digital tools to translate their written explanations into English. This will provide them with key terms in English which can be used to explore the concept in more depth using established glossaries such as the BSL Glossary.

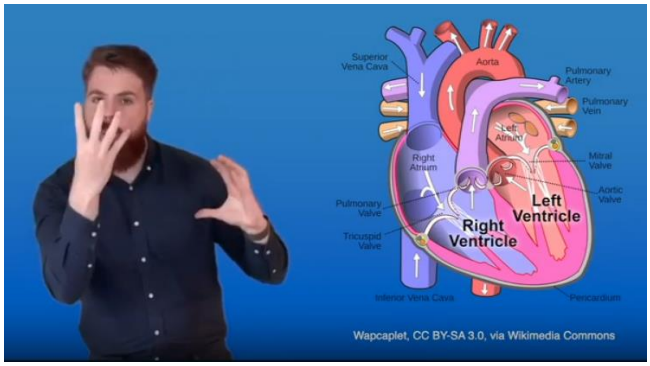
Development and Use of Glossary

In the first part of the handbook, a detailed description of the development process and the work of the team of Deaf scientists is given. Theoretical arguments for the use of STEM glossaries in Deaf education and examples from different subjects to explain how they can be used in the classroom are also given. We recommend that teachers read this chapter to understand the importance of implementing them in the classroom and to get some ideas on how to do it.

How you can use established STEM glossaries in the classroom?

To illustrate how STEM glossaries can be used in the classroom, we will now return to the concept of the heart and see how it is introduced in the British Sign Language (BSL) glossary and how it can be used in the classroom.

Preparation

	First, decide which aspects of the concept you want to focus on in class. Once the focus is clear, your students can still search and go their own way, but to achieve your goals it is important to concentrate on a few central concepts so as not to get lost. We have chosen to focus on the concept of the 4 chambers of the heart, using 3D models to illustrate.

Source: https://www.ssc.education.ed.ac.uk/BSL/environment/venacavad.html

Consider Location, Shape, Function

It is important to consider the location, shape and function of organisms and organs when signing about biological concepts. "For example, when using the sign for HEART, it is necessary to show its location in the body, what it looks like as an organ, where blood flows in and out, and how it fits into the circulatory system. Proper referencing of the sign in the right place is essential to avoid inaccuracies".

Use iconic superstructures to give and preserve a whole picture of the concept

The iconic superstructure of the signed explanation can be used to help students link their own explanations in SL with the signed explanations of the experts. It can also help them to move from their first sign language to different sign languages. Iconic superstructures can be described in text to link STEM signs and STEM words. In our examples Concept Cards and Examples from BSL use a similar iconic superstructure of "chest opening". Iconic superstructures help students to see the concept as a whole and to link different aspects of the concept.

Use of 3D-Models and tangible objects

To describe the location, shape and function of organisms and organs, it is helpful to use tangible biological objects and 3D models. To give an idea of how 3D models can be used to explain ventricles, we have presented the definition of ventricle in the BSL glossary. It shows how 3D models, signs and written terms can be linked together and also linked to familiar signs to create a family of signs in the context of heart chambers and their function. 3D models can be used to create new iconic superstructures.

The table below can be used to create classroom activities and worksheets. For example, the table can be used to create cards that visualize the structure of the ventricles and their function. The teacher can ask the students to bring in the cards in the correct order to describe the chambers in signs and written text.

Example for use of 3D-Models: HEART CHAMBERS

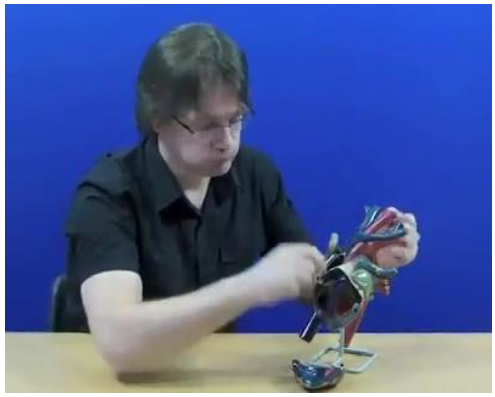
	
model of the human heart	**position**
	
take the heart out of the chest (use of iconic superstructure)	**shaping the heart chamber**
	
Using a model as a reference (boye)	**two chambers below**

	
zooming the model in	**Indicating the lower chambers**

	
changing the position of the model	**pointing to upper chambers**
	
shaping upper chambers	**positioning of upper chambers**

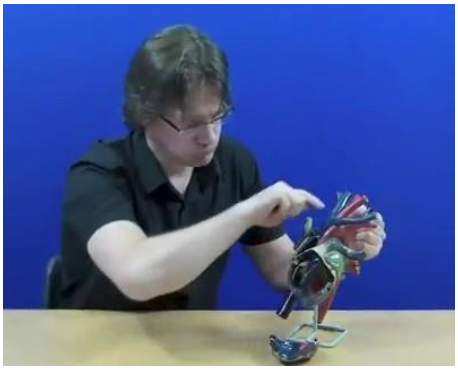
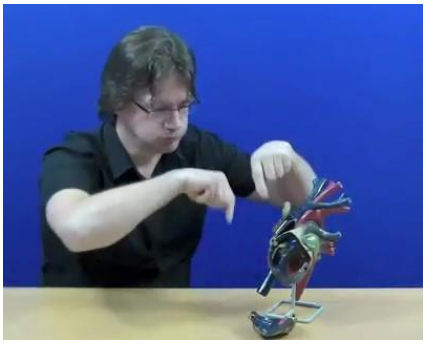
	
direction of blood flow	**finger spelling of ATRIUM**
	
shaping upper chambers	**positioning of lower chambers**

	
using model to locate lower chambers	**two lower chambers**

	
fingerspelling VENTRICLE	**shaping lower and upper heart chambers**
	
imitating the process of blood pumping	**direction of the blood flow**
	
pumping of the blood	

blood pumping and circulation as a process = description of the function

with reference to the 3D-Modell as integral part of signed explanation

The description of the process in SL links several signs of the sign family to create meaningful connections between concepts and signs. It can be used as a starting point, a template for variations or a script for DHH students to create their own explanations and videos.

Source: https://www.ssc.education.ed.ac.uk/BSL/biology/heartchamberd.html

International Sign

5) Use of linguistic and iconic Strategies

Inspired by sign language research, specific didactics of STEM subjects and DeafDidactics, we propose the use of linguistic and iconic strategies to describe, explain and discuss STEM concepts and give concrete examples of how this can be done in the classroom.

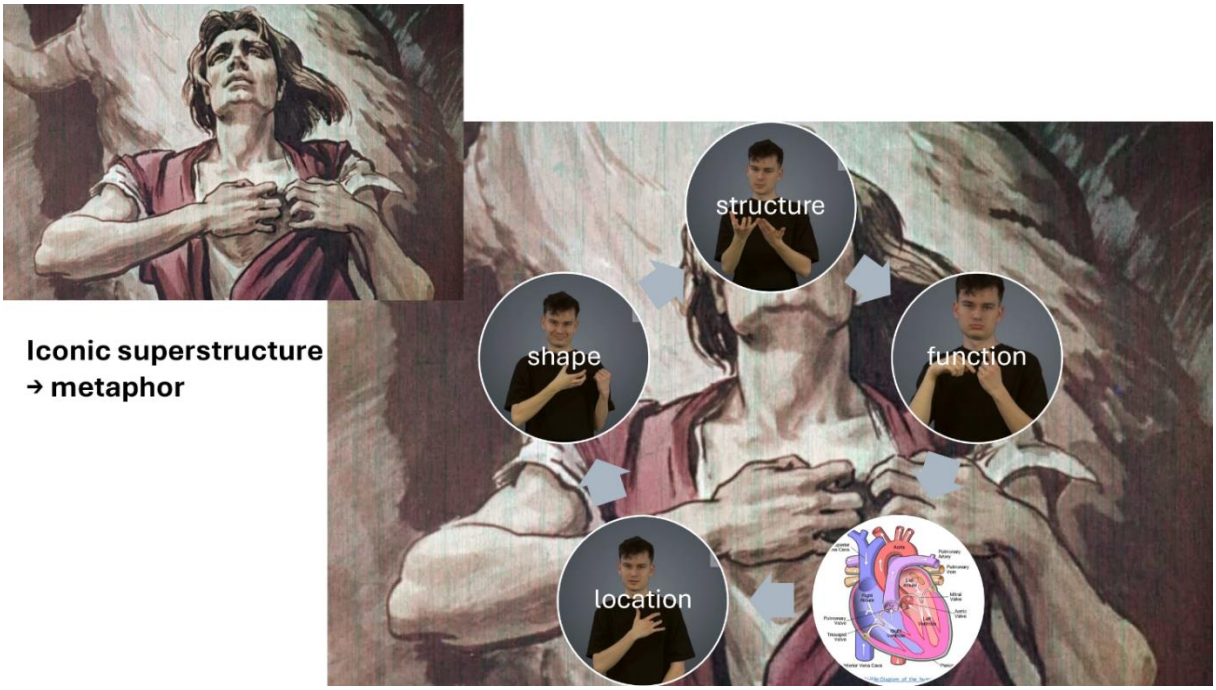
Examples of linguistic strategies:

- use of **iconic superstructures**
- creative **use of space** and
- flexible **change between 2D and 3D.**

Our first example in the last section refers to the use of iconic superstructure in the explanation of a concept of heart and is connected to Concept Cards and STEM Glossaries developed by Deaf experts.

Iconic superstructure in biology

Similar to creative signing in poetry, we replace poems with signed explanations of scientific phenomena problems to introduce iconic superstructure not only as a linguistic but also as a didactic tool. Signed explanations are presented as interactions of conventionalized and creative signs. Iconic superstructure of explanations can be indicated by signed metaphor, which can be similar to metaphors used in poems and films. It creates a context, a scene in which the explanations take place, can be better perceived, interpreted, modified and in this way helps to structure the knowledge of the concepts.

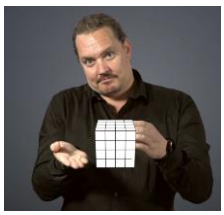


Source: https://diafilm.online/viewing-hall/catalog/40847-legenda-danko/

The example above shows how the poetic metaphor of taking the heart out of the chest can help to create context to describe the location, shape, structure and function of the heart (see diagram below).

International Sign

6) Visualizing Materials in the Classroom - Use of visual Cues



DHH students are often considered as visual learners and the use of visual tools is recommended for STEM classrooms. However, meaningful use of visualizations in STEM education requires embedding them in signed, written or spoken explanations (texts, videos) adapted to individual perceptual situations and linguistic repertoires of deaf learners.

Appropriate coordination of multimodal resources

Some of the difficulties that many Deaf students, interpreters and teachers may face in the STEM classroom are often related to the use of multimedia and digital technologies. At this point, it is crucial to develop strategies for coordinating multimodal resources in the STEM classroom.

While spoken explanations can be used in parallel and simultaneously not only with pictures but also with experiments or animations, it is not always helpful, especially for learners with little SL experience, to offer videos of experiments or animations and simultaneously signed explanations that are not interwoven with experiments or animations. In order to avoid visual overload, it should be carefully planned in advance how animations and experiments can be combined with signed explanations and not only translated after the experiment has been carried out.

Pictorial and schematic Images

Another important didactic issue is the use of inappropriate diagnostic and instructional materials that do not encourage the use of sign language and visualization techniques and use only written text. These can lead to uncontrolled and widespread use of pictorial images by deaf learners and prevent them from creating schematic images to solve problems.

The use of pictures, animations and experiments without the possibility of embedding them in signed, written and spoken explanations created by DHH learners, teachers and/or interpreters can lead to the dominance of pictorial over schematic and dynamic images. However, "silent materials" can be used as impulses for discussions and descriptions in sign, written and spoken languages adapted to the particular sensory, motor and linguistic prerequisites of the learners and thus provoke the creation of not only pictorial but also schematic images.

Reading of scientific texts

Thematic and pictorial images evoked in the context of sign explanations can help DHH learners move on to encoding the meaning of scientific texts by linking words to signs.

Meaningful use of visualization strategies and processes

Students both enjoyed and struggled with the overwhelming power of visualization over their thinking. They engaged in the mathematical activities because they were attracted by these visualizations and what they could do with them; but they were frustrated by how often their eyes led them to focus on irrelevant aspects and to miss the main conceptual point of the representation.

Based on research in mathematics education and deaf education, we explained in the first part of the handbook why it is so important to embed visuals, models, sketches, and experiments in signed descriptions to ensure meaningful use of visualization strategies in the classroom. In the chapter Signed Geometry we described how visualization strategies can be part of the problem-solving process.

Connecting STEM education and linguistics of sign languages

Building on considerations focused on geometry, we would like to go further and refer to the linguistic framework to gain a better understanding of visualizations in other STEM fields and to find ideas for designing new methodologies.

It is argued that signers and speakers coordinate a variety of intentionally expressive actions to interact and communicate. They characterize description, indication, and representation as different forms of signaling that can be used alone or in combination with others to create meaning. Iconicity as a property of signed and spoken languages plays an important role in the combination of description, indication and representation, as will be seen below.

Table 11: Cuts 7-9 and cube division in smaller cubes (imagistic, diagrammatic, metaphorical)

Building on that, we propose to understand iconicity as a resemblance between linguistic form and certain properties of scientific phenomena or mental images of these phenomena created by humans, supported by sensory and motor perception and action. The similarities are provoked by three types of iconicity:

*"**Imagistic iconicity** is resemblance in quality,*
*while **diagrammatic iconicity** is resemblance in relations or structure,*
*and **metaphoric iconicity** is resemblance by association"*

Ferrara, L. & Hodge, G., (2018). Language as Description, Indication, and Depiction. *Front. Psychol.* 9:716. doi: 10.3389/fpsyg.2018.00716

Example from Biology: METAMORPHOSIS

In order to extend our recommendations to other subjects, we will now use an example from biology and provide you with concrete suggestions and teaching materials.

Imagistic Iconicity

	In our example, Imagistic Iconicity can be illustrated as the resemblance of the shape and form of a caterpillar, chrysalis, or butterfly. To use Imagistic Iconicity in learning about biology concepts, DHH students can be given screenshots of the characters and asked to transform the hands into a butterfly by painting or sketching. DHH learners can also paint their hands directly into butterflies or fingers into little caterpillars and then imitate the animals' movements to describe them.

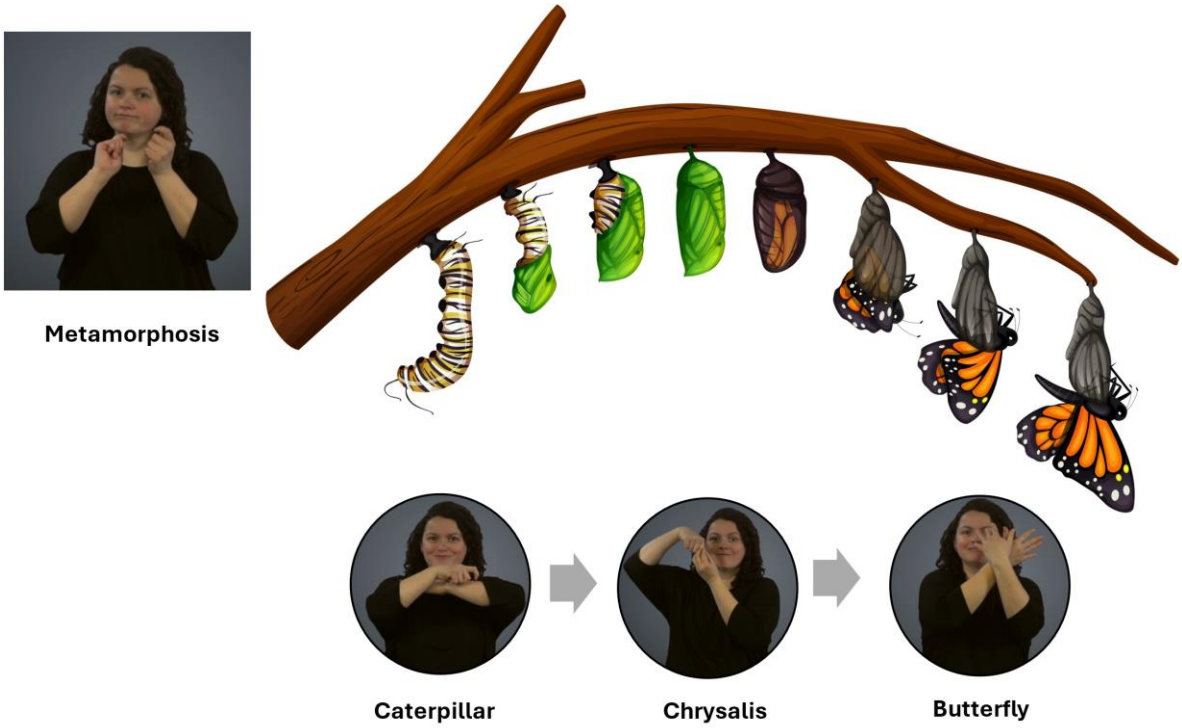
Using glove or finger puppets (caterpillar, chrysalis, butterfly) and acting out the story with puppets could also help young learners connect signs, visuals and concepts and help learners move from imagistic to diagrammatic iconicity. This will prepare a more flexible use of visualization strategies and visual cues and enrich not only the linguistic and multimodal repertoire but also the repertoire of learning strategies.

4 wonderful finger puppets caterpillar, bee, cat, bear handmade - Etsy.de

Diagrammatic Iconicity

Diagrammatic Iconicity can help describe the process of transformation from caterpillar to butterfly and give meaning to the term METAMORPHOSIS. To express metaphorical iconicity, students can be given the diagram above. They can also transform the diagram into a cycle diagram.

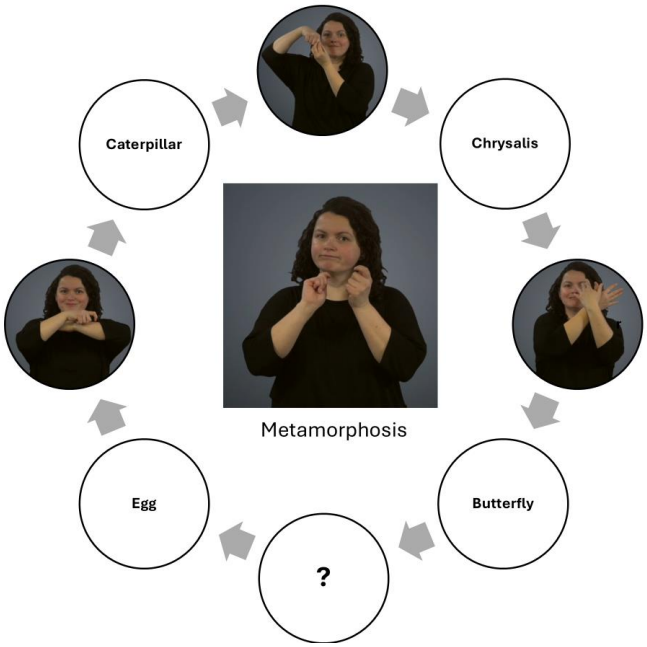
The form of the sign for CYCLE or CIRCLE is similar to the form of the sign for METAMORPHOSIS. The cycle diagram can be used to explore diagrammatic symbolism and to gain a deeper understanding of the concept.



It seems to be crucial to give learners the opportunity to create their own visualizations, rather than merely watch, fill in or even use teacher-generated visualizations.

Modifying and varying the diagrams invented by the teacher/interpreter and creating their own schematic visual tools will help them to embed them in their own linguistic and multimodal strategies and in this sense to think diagrammatically.

On the next page, you will find a possible modification of the diagram that raises the question of who should create the new sign terminology and invites the DHH students to look more closely at the concept map to find the lexical item for EGG.



Metaphorical Iconicity

The transformation of the caterpillar can be used as a metaphor to describe the transformation of the character of the person or situation. Learners can be invited to explore the metaphorical iconicity of mepamorphosis and perform their own little story in written, signed or spoken languages.

The Wonder of Caterpillar

Watch the video. Write your own story. Create your own pictures.

_____

_____ _____ _____

Author/s:

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7) Creation of Sign Language Video Clips explaining selected STEM Concepts – Online Presentation

To develop sign language skills and increase STEM knowledge and competencies, DHH students may be asked to create their own videos in their sign language, documenting their own science experiments, internet or literature research, reflections, discussion of results, collaboration with peers and, if possible, STEM experts outside the school.

The goals of student video development are

- to expand their linguistic and multimodal repertoire,
- to develop STEM talent and creativity
- to use the videos to revisit their STEM knowledge, STEM concept understanding, and language skills,
- to create video content and materials for future STEM instruction, adapted to the needs of the peer group.

Use of Language Strategies and Meaningful Visualization Strategies in Videos Created by DHH Learners

In the previous sections, we explained how language strategies and visual cues can be used as tools to teach STEM and illustrated them with examples from biology and mathematics. These examples can be used as a starting point to give your DHH students ideas about how to start working on their own videos. In the next section, we will look at geography.

Use of Expert Interviews, Concept Cards and STEM Glossaries

Sonnensystem_DE4psS1.mp4

The materials provided by STEMSiL can not only provide inspiration, but also concrete examples and language tools that can be used to create STEM videos in sign languages.

How can you use the concept cards to motivate DHH students to create their own videos? To start, we suggest you to follow these steps.

1. Show your students a concept card explaining the rotation of the Earth and the change of seasons without showing them the schematic diagram used to create the explanation.

2. Ask students to draw the diagram or build a model of the phenomena explained on the concept card.

3. Reflect on the video and discuss the strengths and weaknesses of the explanation. Invite students to make their own video. Suggest that they use the diagrams and models they created.

To expand their knowledge or find the appropriate technical signs, DHH students can look up Earth rotations or familiar concepts such as the solar system, for example, on the STEM Glossary created by Deaf STEM experts.

https://www.facebook.com/sign2mint/videos/dienstag-mit-sign2mint-alle-planeten/1039918489867648/

Use of additional digital resources and rising of public awareness

Although there are now many helpful resources available on the Internet, DHH students will quickly realize that there are few resources on the Internet that offer explanations in sign languages that can be fully understood, although some do offer subtitles and helpful visualizations, such as „Warum gibt es Jahreszeiten? „ (*‚Why are there seasons?'*) provided by Simple Club: https://www.youtube.com/watch?v=_EJv6c4ogQE

For this reason, DHH learners can use parts of the videos that are not accessible but also research the barriers and report them to the content creators. This could help raise public awareness about sign language and deaf communities.

DHH learners can even start collaborating with companies like Simple Club or Real-Life Guys and help STEM experts without sign language skills and connections to the Deaf communities to optimize their learning materials.

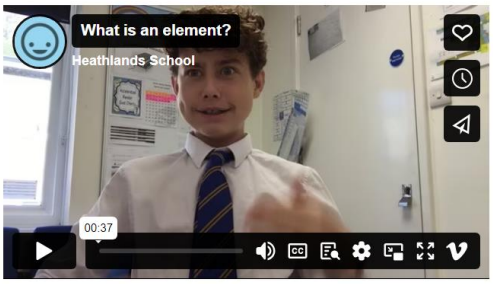
Collaborations with museums, laboratories and planetariums

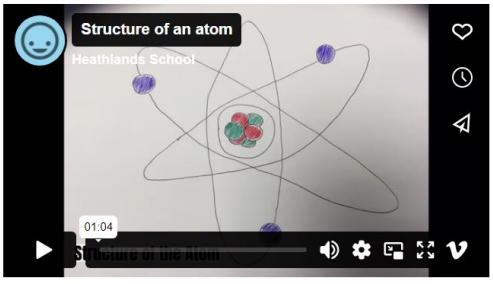
Collaborations with planetariums, laboratories, and technical museums can be mutually empowering. Museums, planetariums and laboratories equipped with instruments, models, original recordings, special technical tools, stages and rooms can be a stimulating environment for creating video content for learners on the one hand. On the other hand, collaborations will reveal hidden barriers and SL languages as tools to overcome barriers in technical museums, planetariums and laboratories, which is at least in part the case for the Technical Museum in Berlin.

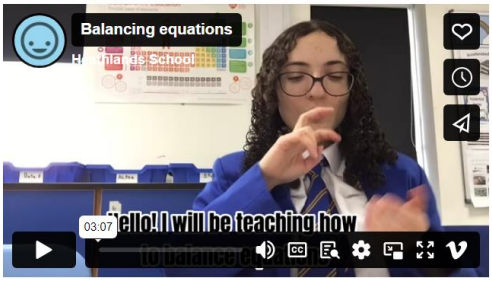
Examples of STEM videos in sign languages created by DHH learners

Useful examples for videos explaining concepts from chemistry, biology and physics created by DHH students can be found on the science teaching channel of Heartland School for the Deaf.

Heathlands School for the Deaf - science teaching channel







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8) STEM Dialogue in and outside the Classroom: Short Presentation and Discussion

To promote dialogue and cooperation between different schools, other educational and research organizations, we suggest implementation of

- STEM competitions,
- STEM slams,
- STEM summer camps.

Sign Language Poetry Slams

In Deaf communities, sign language poetry slam is a very well known form of performance where deaf / sign language performers compete against each other to determine the winner. There are also Sign Language Poetry Slams for young people and even children. This kind of performance is an important cultural and social event in Deaf communities.

STEM Competitions

On the other hand, there are various math or STEM competitions around the world that help learners discover their talents and compete as individuals or in groups. However, STEM competitions are usually conducted in written or spoken language, which might make it inaccessible for many DHH learners to participate.

STEM Competitions

We suggest combining elements of Deaf / Sign Language Poetry Slam and STEM competitions to create new formats of competitions with mathematical problems, STEM experiments or computer science challenges in sign languages.

STEM summer camps or STEM weekend clubs can be used as projects to prepare for Deaf STEM competitions and to create a space where scientific discussion of STEM phenomena can emerge and be expressed directly in sign languages and not just translated afterward.

Interacting with professional programmers who participate in large championships like Robocup can further motivate learners. Together with DHH learners, you can visit universities where robots are trained and programmed to play soccer, for example.

The creation of STEM videos in SL by learners described in the previous chapter can also be organized as a STEM competition.

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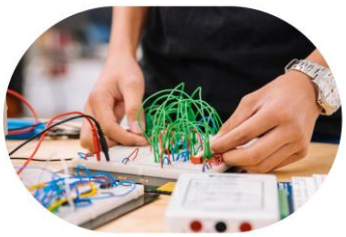
9) Use of Co-Creation Toolkit – with Technology Tools



The use of technology can help connect the teaching of different STEM subjects in SL through the use of

- programming,
- Lego creations,
- robotics,
- technology to work with materials such as wood, metals, etc.

In the previous section, we introduced the idea of deaf /sign language STEM competitions and how to motivate DHH students to participate. One way to prepare them for the competitions is to use established programs such as those provided by Lego Education in combination with the SPIKE™ Prime Set. Visit the Lego Education website for lesson plans and student materials: https://education.lego.com/en-us/lessons/prime-competition-ready/

Competition Ready as example

What are the goals of the Competition Ready unit? The goal of this unit is to introduce students to the world of robotics competitions and give them the opportunity to learn the basics of building and programming autonomous robots using sensors. The next goal is to help students learn how to work together to build a robot for competition. Students are expected to systematically test and refine programs, use the design process to develop a problem solution, and complete missions. The target audience is students in grades 6 to 8. The cultural background, linguistic and multimodal repertoire and special perceptual situation of DHH learners are usually not considered in the original design of the learning materials.

Identify hidden inaccessibility and look for way to break them down together with your DHH students

To prepare for the unit, carefully study the teacher resources, especially the student materials, to identify hidden inaccessibility and find ways to overcome them with your DHH students. You can also invite your DHH students to review the materials together and report back to you on the inaccessibility they have identified.

To identify inaccessibility, you can try to see if you can understand videos without sound. If not, you may need to add subtitles or at least write down the explanation to make it more accessible. It would be useful if teachers and interpreters make them accessible by providing interpreting/translation.

Algorithms, diagrams, pictures, and videos can facilitate understanding, but they cannot remove all communicative barriers. The first part of the lesson can be cooperative translation of materials with the support of the teachers, interpreters/translators or other experts competent in sign language(s). Use the materials and methods described in the previous sections to remove barriers using sign language(s). See the co-creation guide for more information.

Construction Plans

https://assets.education.lego.com/v3/assets/blt293eea581807678a/blt06873e1b438a0d7e/5ec8e66f033ad5045f4c79a6/driving-base-bi-pdf-book1of1.pdf?locale=en-us

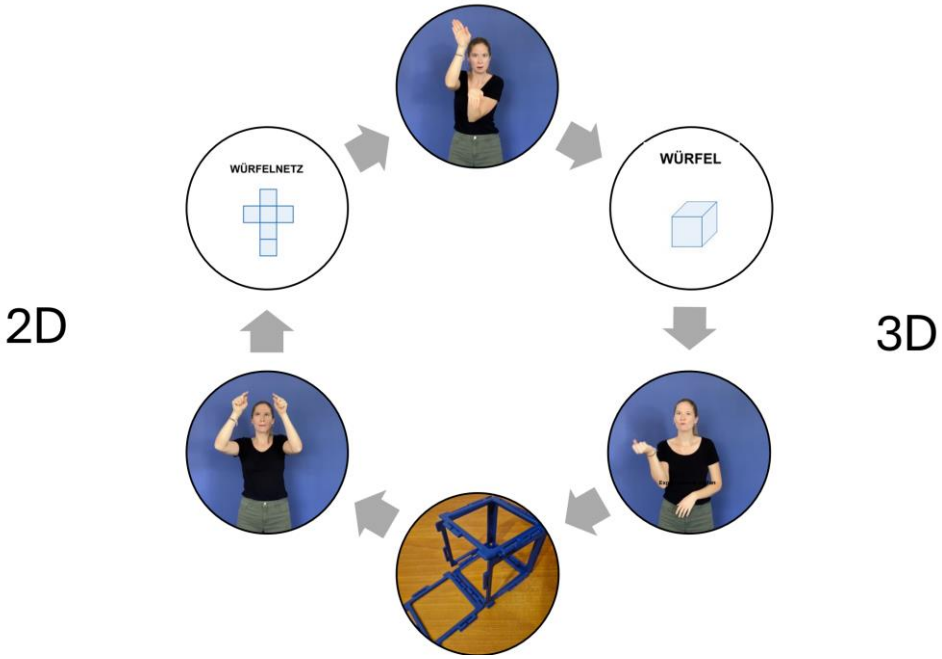
International Sign

10) Use of Co-Creation Toolkit – without Technology Tools

As an alternative to experiments that use technology, we recommend conducting experiments that use handicrafts and require direct contact with nature, materials, or each other.
This will give DHH students the opportunity to use STEM vocabulary, to provide explanations and to take advantage of iconic superstructures to describe the experiments directly from the actions, visible and tangible properties of the objects and core phenomena studied by the experiments.

Flexible change between 2D and 3D
DHH students can use Magformers or the Polyhedron Construction Kit to explore geometric shapes and flexibly switch between 2D and 3D, which can be expressed in sign language(s) more easily than with words or sketches.

Handling constructions - Signs derived from actions
DHH students can conduct the experiment by constructing certain solids in space (3D), such as cubes, or figures in the plane (2D), such as meshes. As a next step, they can try to describe plane objects by using their fingers as drawing instruments or make cubes by imitating the throwing of imaginary dice. The signs for folding and unfolding the cube are derived directly from the action in the experiment. Reflect on the iconicity of the signs and parts of the experiment to ensure understanding.



For more ideas and concrete examples of how to conduct biology, chemistry, and physics experiments in BSL, visit the Science Education Channel at https://heathlands.herts.sch.uk/science-teaching-channel/.

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