

# Concept maps in education

the complete guide

## What is a concept map?

A concept map is a way of representing information, knowledge, or facts in a graphical form. It consists of concepts and relationships between them. A concept in the map is anything we want to talk about, i.e., any real-world object, an abstract term, an event, or even a fact. Concepts are usually represented by text in rectangles and relationships as oriented links between the rectangles, with arrows showing the reading direction.

Two concepts and the relationship between them form the basic unit of information and the building block of concept maps. To give an example, the fact that the Earth orbits the Sun could be represented by the simple concept map in figure 1. "Orbits" is the relationship, in figure 1 represented by a word and two links (which is just an aesthetic nuance) ended by an arrow. Sun and Earth are two concepts.

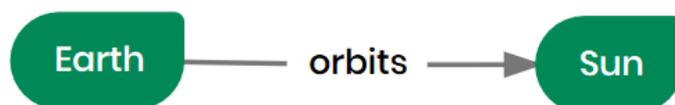


Figure 1: a concept map saying the Earth orbits the Sun

A concept in the map can be linked by any number of relationships to other concepts. To illustrate that, we can extend our concept map to include the Moon, NASA and how these concepts relate to those we already have on the map. That could result in the concept map in figure 2.

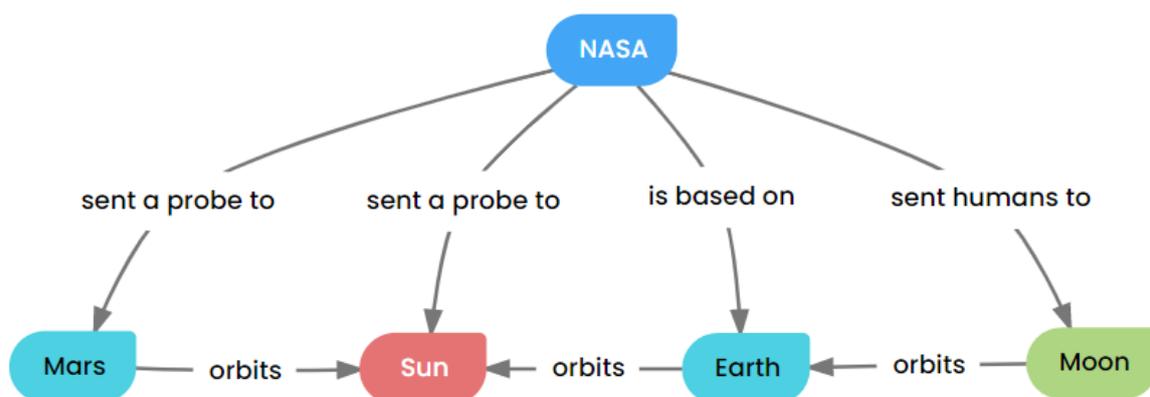


Figure 2: A concept map about NASA exploration of the solar system

This map tells us that NASA has sent humans to the Moon, is based on Earth, sent probes to Sun and Mars, and plans a mission to Mars. It also includes the information about which of the objects orbit which.

## Concept maps origin

Concept maps were developed by a team lead by Joseph Novak in 1973 during their research on the psychology of children's learning based on Ausubel's theory of learning. One of the core notions of Ausubel's theory is the distinction between **rote learning** and **meaningful learning**. Rote learning means memorizing unconnected facts. Meaningful learning happens when new facts and concepts are linked to those that students already know, i.e., when new information is integrated with current students' knowledge. **Information acquired through meaningful learning is remembered for a longer time, and, even more importantly, there is a higher chance that students will use it successfully** than rote learning.

Prerequisites for meaningful learning.

There are several prerequisites for success in meaningful learning.

First, the learner must be motivated to participate in the learning. Second, the new information must be presented in a way that enables relating it to what the learner already knows. The first condition is hard to influence as it depends on many factors. However, as Novak found out, concept maps can help with the second. They can explicitly include the relations between the concepts already known by the learner and the new concepts that are to be learned. Of course, to prepare such a map, the teacher must know very well what the students know, or the students have to create the map themselves.

## Benefits of using concept maps in education

An excellent example of how big an effect concept maps can have was given by (Novak 2010). A high school in Costa Rica decided to start using concept maps in all subjects for both instruction and assessment. As a result, in four years, the success rate in National High School Graduation Exam increased from 65 % to 100 %.

The main benefit of concept mapping is **achieving meaningful learning instead of rote learning**, i.e., students understand the information they acquire and so remember it longer and can use it more successfully.

Apart from that, concept maps have numerous other advantages:

- They can provide a quick, systematic overview of the given topic.
- They emphasize relationships among concepts.
- Their quality can be (to some extent) assessed automatically through evaluation rules.
- They can encourage collaborative learning.
- They can be used to actively involve students by giving them a partially filled map to be completed.
- Students with good visual recall remember them better than text.
- They can serve as a basis for discussion.

- They can be used for curriculum design, helping to achieve integration and continuity in the course. It can also increase awareness of the importance of the course.
- They help to explain why the given concept is worth knowing (Allen 1993)
- They encourage students to think creatively about the subject.
- They also encourage critical thinking.

## Key aspects of successful concept mapping

According to ([Novak and Cañas 2008](#)), students start to understand concept maps only after they try creating them independently. It thus **takes some time before concept mapping starts bringing benefits** after it is introduced to a particular group or school. Students' exams might even worsen for a short time until they get familiar with concept mapping and start improving.

There are usually **many possibilities of how to create a map** on one topic. Even if two map authors had the same entry knowledge and were assigned to create a map with the same set of concepts, they would probably end up with slightly different structures (or layout) and different relationships. It thus might be hard to read a map created by someone else. On the other hand, **concept maps serve their purpose best if each student develops the map by himself** or at least edits a map created by someone else, adapting it according to her needs.

Although the students might feel that creating and editing concept maps is hard work, modern **software tools like ContextMinds allow creating new maps quickly and easily**. For example, ContextMinds automatically suggests new concepts suitable for adding to the map, according to the context set by the concepts already present in the map. That means that students can draft the map almost without typing and **focus on thinking about the relationships**.

## How to create concept maps

We present here a slightly extended version of the guide proposed by Novak and Cañas (2008).

### Choose the topic

The first step is, of course, choosing the topic of the concept map. Novak recommends creating each map to answer a focus question (e.g., Why do the seasons change on Earth?) instead of just a general topic (e.g., The four seasons). The difference between stating a focus question and just selecting a topic is often tiny. However, the focus question helps determine the size of the map – it helps us decide what we should include and what we can omit.

For example, let's say our topic is photosynthesis and we chose the focus question "Why is photosynthesis important." Encyclopedia Britannica directly answers it, so we can take its article <https://www.britannica.com/science/photosynthesis> as a base source of information.

## Think about the audience

This brings us to the second decision: what is the intended audience of the map. Obviously, a map for high school students will be very different from a map on the same topic but intended for use at a university. Ideally, the author of the map should be aware of what the audience knows and does not know. This way, the map can include some concepts already known by the students and the relationships to the new concepts they are supposed to learn. An option proposed by Novak is creating expert skeleton maps, maps created by experts including only the most important core concepts and relationships between them. Such maps can then be quickly finalized by the teacher to fit the target audience or directly by the students on their own. However, even the expert skeleton maps should be created with some level of detail in mind, i.e., we have to know how specialized the map should be, what technical terms it should include and how deep into the topic it should delve.

For our running example, let's say our audience is high school students already familiar with concepts like green plants and herbivores.

## Select key concepts

Answering the first two questions should enable us to choose a set of key concepts the map should include. Those are the concepts that are to be explained by the map. There should be at most 25 such concepts. If we gather more, we should consider splitting the map into several smaller maps. Finally, we order the key concepts according to their importance.

From Britannica's answer to our focus question, we gather the key concepts *photosynthesis*, *energy*, *photosynthetic organisms*, *higher life-forms*, *oxygen*, *carbon dioxide*, *water*, *food*, and *energy-rich organic compounds*. The text also speaks about the cessation of photosynthesis. To make it into a concept so that we may speak about it, we might add *Earth without photosynthesis*.

As this is a small map, all concepts are similarly important, so we might as well take them in this order.

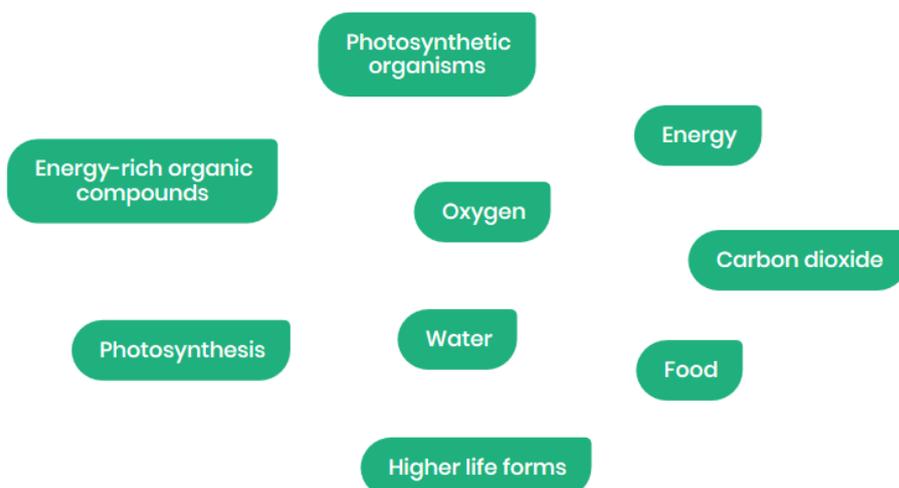


Figure 3: Selected key concepts

## Add a few known concepts

To create a good concept map, the key concepts should include several concepts that are related to others, but the target audience is already familiar with them. Including known concepts greatly supports meaningful learning as the students will see explicitly how the new concepts are related to those they know.

We can expect that our students don't know the concepts *photosynthetic organisms*, *higher life-forms* and *energy rich organic compounds*, so we add the concepts *green plants*, *herbivores*, *sugars* to include some examples the students are familiar with.

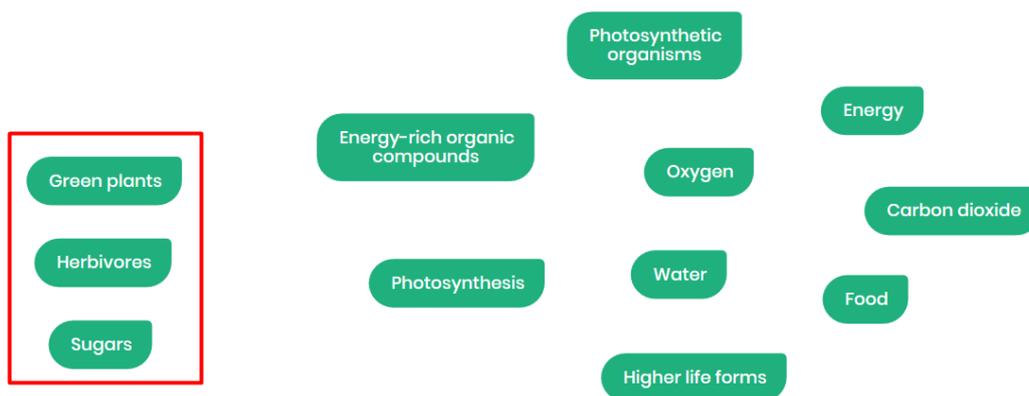


Figure 4: Preliminary map with added known concepts

Try to use the context suggestion in ContextMinds. The context suggestion shows concepts that are related to the concepts on the map. It can help you create the concept map faster and more easily.

## Place concepts on the map

Now we start placing the concepts on the map. We should place the most important one on the top of the map first. Then we continue adding other key concepts.

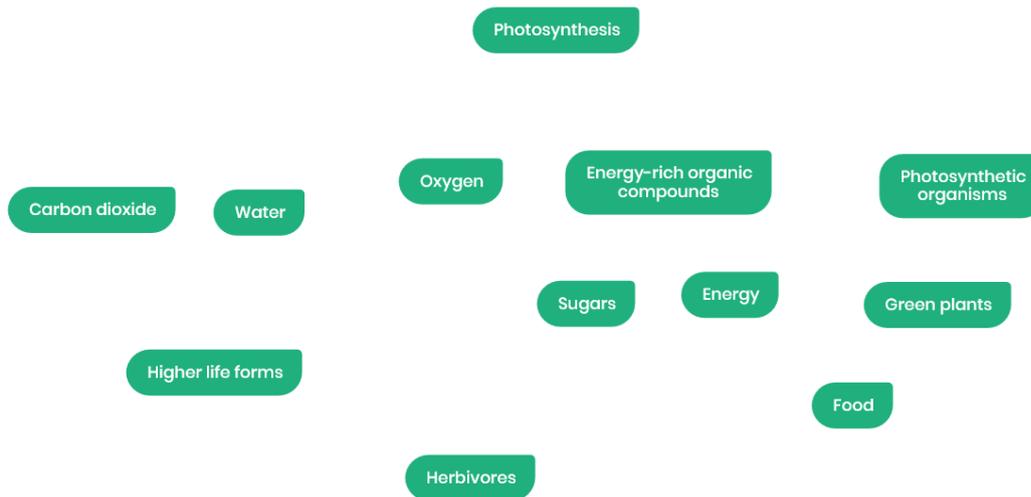


Figure 5: A preliminary map with placed concepts.

## Connect concepts with relationships

The next step is connecting concepts together with relationships.

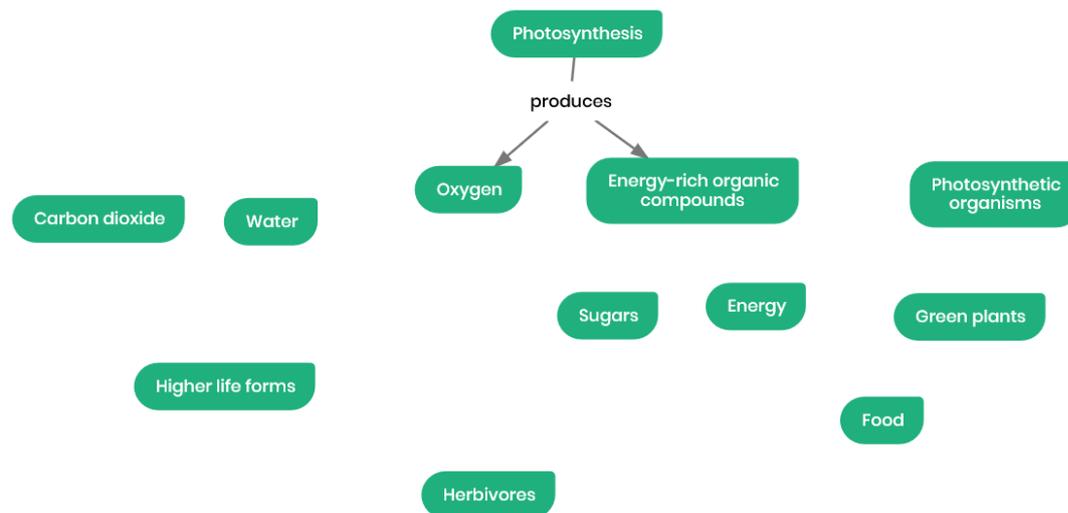


Figure 6: A preliminary map with the first connection between concepts.

## Recommendations for creating a concept map

There are several recommendations on how to place and connect the concepts. (Derbentseva & Kwantes 2014)

- Similar or highly related concepts should be placed close to each other. When possible, we should cluster concepts into groups covering some subtopic of the map.

We could rearrange our map to more clearly separate the "consumes" group and "produces" group, as indicated in figure 7.

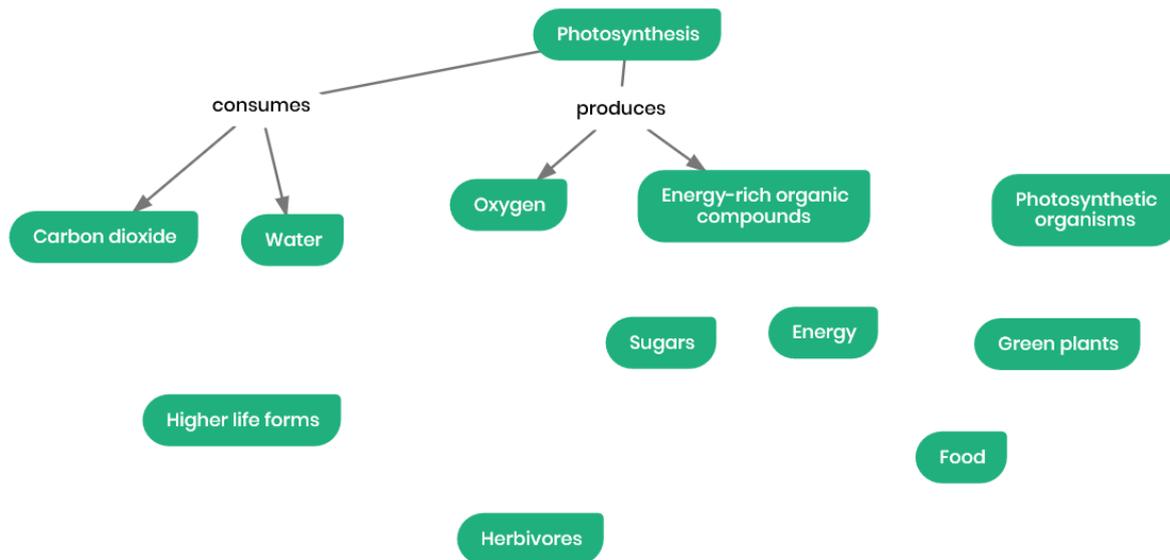


Figure 7: Photosynthesis map regrouped

- The layout should be aligned with natural reading order, which is usually left to right and from top to bottom.

This rule usually cannot be followed throughout the whole map, as we need to use the space on both left and right sides.

- Chains of links (relationships) should be as continuous as possible. We should choose the direction of the relationships in such a way that they can be followed (as far as possible) from one concept to another without interruption in the form of an opposite direction link.
- We should choose the active voice for the relationship labels.
- Each concept should be linked with some relationship to at least one other concept – preferably the most related one.

That is already accomplished in our map.

In our map, the two above-mentioned recommendations are violated by the links around photosynthetic organisms and Higher life forms. We can change the passive voice to active ("is performed by" to "occurs in"), as shown in figures 8 and 9. Also, we can switch the directions between Higher life forms and Herbivores.

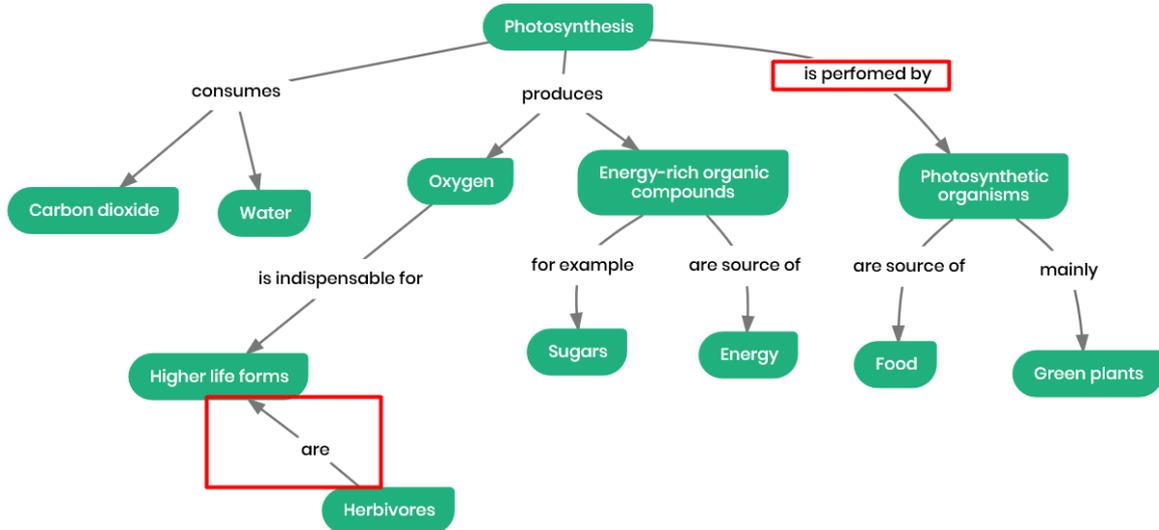


Figure 8: Concept map with errors

In the final stage, we might end up with a map looking like in Figure 9.

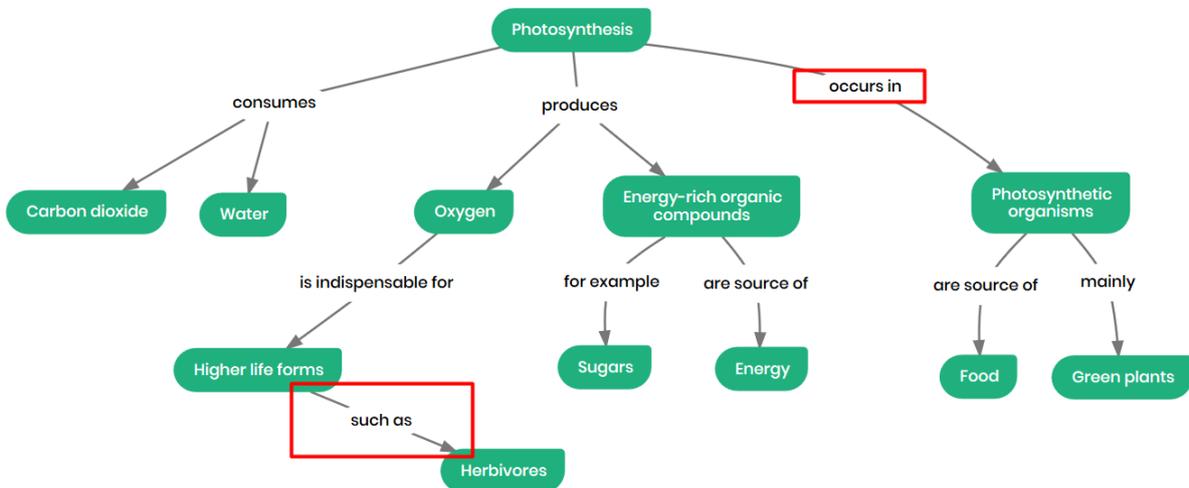


Figure 9: Changing the direction to achieve continuous link chains and using active voice instead of passive voice.

## Add additional concepts and relationships

After we have placed and interlinked all key concepts, we can also create additional relationships (cross-links) between more distant concepts – provided that it would make the map clearer or easier to understand or that the relationship is very important.

Following the same principle – if it makes the map clearer or easier to understand – we can also add other concepts and link them to our key concepts.

In our map, we might add explicit links between *Higher life-forms*, *Food and Oxygen*, *Energy-rich organic compounds*, and *Photosynthetic organisms*, *Higher life forms*, *Carbon dioxide*, and *Water*, as shown in figure 10.

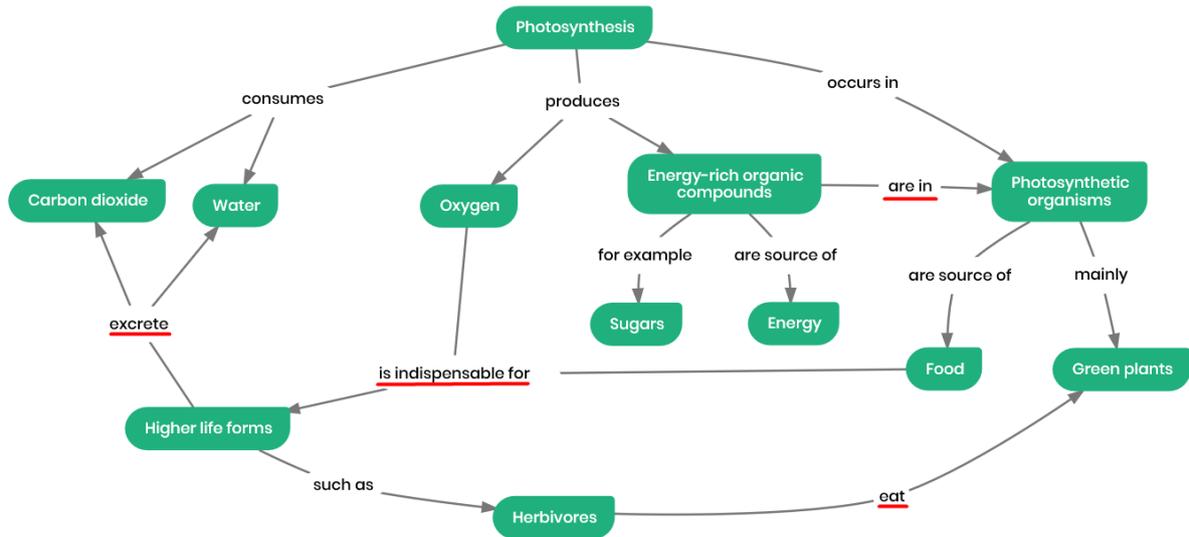


Figure 10: A map with added relationships (cross-links)

The concept map shows the importance of photosynthesis for life on Earth since it produces oxygen and energy-rich organic compounds, such as sugars. Photosynthesis occurs in photosynthetic organisms, which higher life forms use as a source of food. At the same time, higher life forms excrete carbon dioxide and water, which in turn are used by the photosynthetic organisms during photosynthesis.

## Remove redundant concepts or relationship

We might also find out that some concepts are unnecessary.

We can see that the map does not further explain how photosynthesis creates energy. We might remove that concept also and save it for another map that would focus on the actual process of photosynthesis.

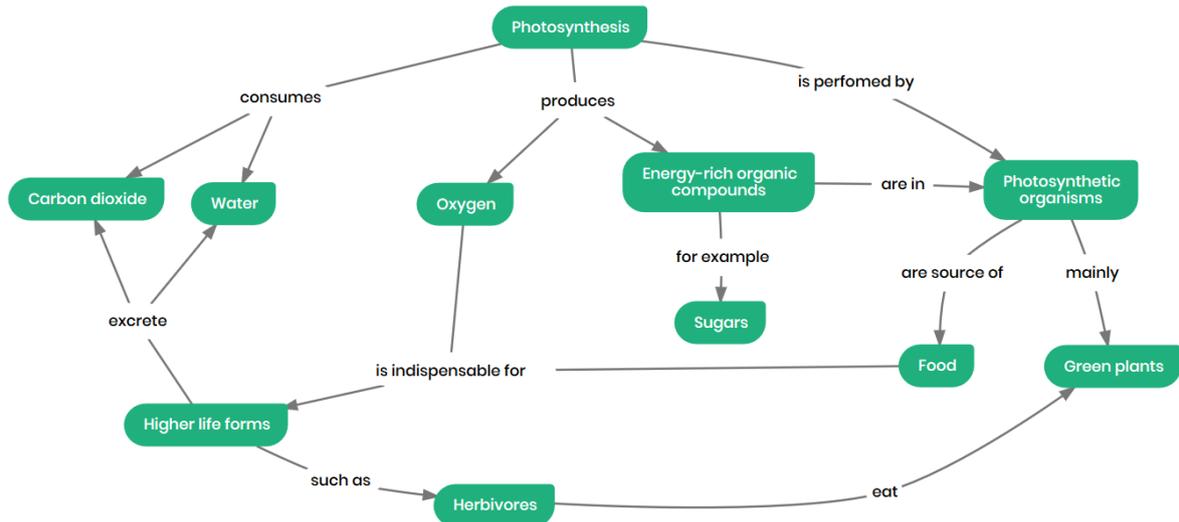


Figure 11: Map on "Why is photosynthesis important" with redundant concepts removed.

### Concept, relationship or just a note?

Sometimes it is unclear whether something, usually an event or a fact, should be in the map represented as a separate concept, or just as a relationship between other concepts. A good rule of thumb is the question "Do we want to talk more about the thing (event, fact) in the map? Will we want to link it to more than one other concept?" If the answer is yes, then it should be a separate concept. Otherwise, we might consider representing it with just a link to make the map simpler.

Let's say we are creating a map about what NASA does. We would probably just mention that it landed humans on the Moon using a relationship between NASA and Moon as shown in Figure 12. However, if we were focused more on the moon landings, we could, for example, create a separate concept "NASA Moon landings" and linked it to, e.g., particular Apollo missions, astronauts involved, etc., as indicated in Figure 13.

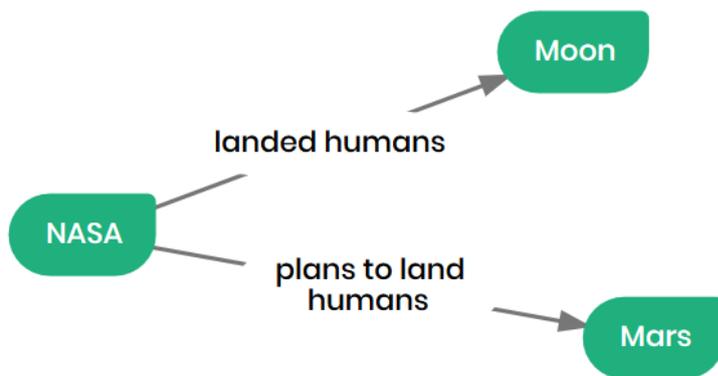


Figure 12: A concept map where the moon landing is just a relationship

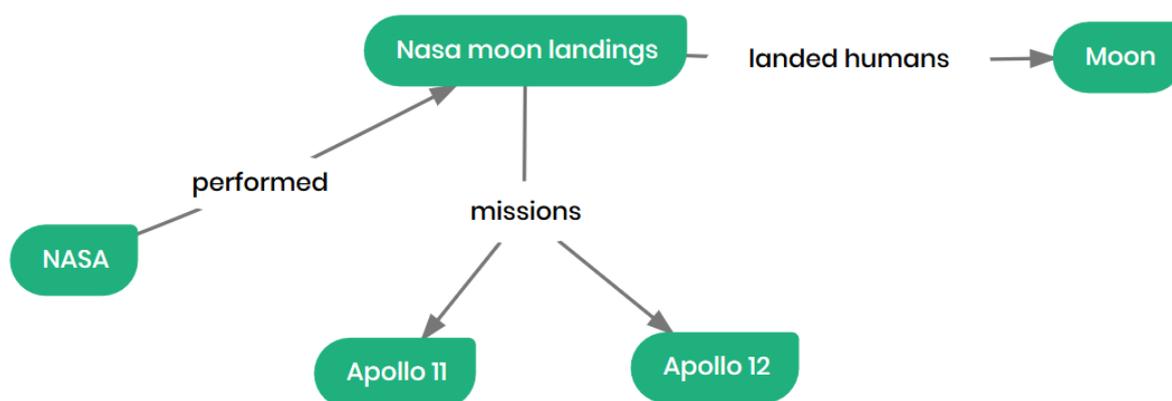


Figure 13: A concept map where moon landing is a separate concept

In ContextMinds, there is another option of including information in the map: we can add notes or links to concepts or relationships, which are then shown when users select a concept. For example, if we were creating a map about various space agencies like NASA and ESA and their future plans, we can add information about the history of the agency, including the moon landing, just as a note, as it wouldn't be a key concept with respect to such a map.

## Using concept maps in education

### Introducing concept maps to students

Proper introduction of concept maps to the students is essential to achieve any benefits from using concept mapping. The best way is to prepare the introduction according to the students – considering their age, knowledge, capabilities, motivation, etc. The goal is to catch their attention and convince them that after the initial learning effort, concept maps will help them to achieve better results and easier studying.

You may try to use this tutorial to first introduce the basic theory behind concept maps and meaningful learning and point out the main benefits of concept mapping.

A possible starting point is then showing the students a concept map summarizing the topic of a previous lecture or some general concepts from the current subject – for the students to be already familiar with the concepts so that only the way of their presentation is new. We can start by revising the topic while showing each concept and relationship on the map during the lecture.

It is important to get students actively involved as soon as possible. The above-mentioned first map can be intentionally prepared incomplete, and we can encourage students to suggest what concepts and relationships should be added. An example of an incomplete "skeleton" map on our example with photosynthesis could look like figure 14. Correct inaccurate suggestions, and after reaching consensus, add each such new concept and relationship directly to the map. Finally, share the map with the students by sending them a web link to it if the software supports it.

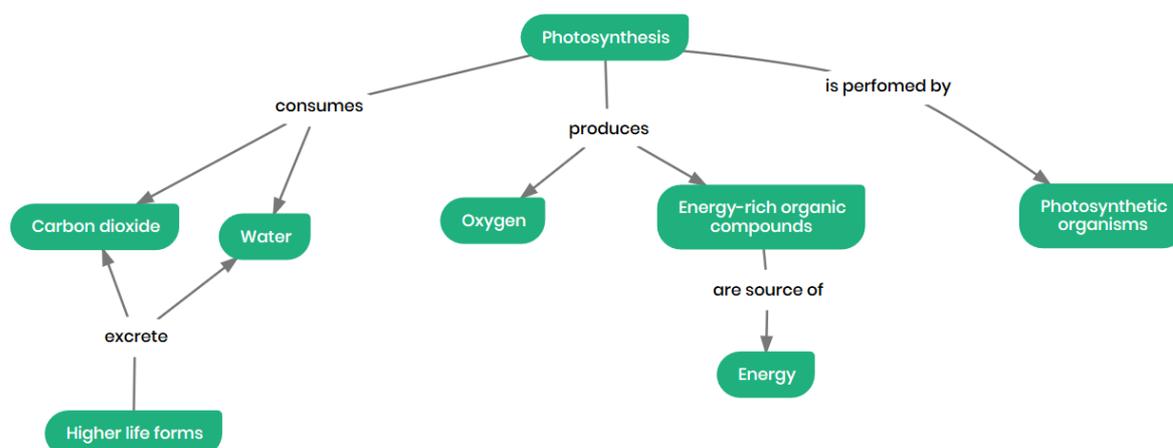


Figure 14: A skeleton map on Why is photosynthesis important.

At the end of the introduction, give the students a link to another incomplete map to finish it as homework. Don't make it compulsory, try rather offering them some reward for finishing it. In the next lesson, go through the maps handed-in by students (hopefully, there will be at least a few) and point out what is correct and what is wrong. Remember that this is not a "lost time" – all the time spent looking and working with concept maps is at the same time a possibility to learn, revise or correct misconceptions.

Then you can continue by showing a concept map with a new topic, according to the course plan, and either giving a lecture with its support or again asking students to suggest concepts and relationships to complete it – this depends on the level of students' enthusiasm, time capabilities and number of students in the classroom. It might be not feasible to discuss the map creation in a lecture hall with several hundreds of students.

Once you feel that students are familiar with concept mapping, you can start using them all the time and include other techniques shown below.

## Using concept maps for instruction in lectures

There are three main ways of how to use concept mapping directly as a supportive tool for lectures.

- Show a prepared complete map and use it instead of a classic "power-point" presentation.
- Show an incomplete map and encourage discussion with students on how to finish it during the lecture (as indicated above).
- Start from scratch and create the map during the lecture, adding concepts as you explain them.

Preparing the whole map in advance might be quite time-consuming. However, with the help of modern software tools, it should still be feasible. Another option is to find a map created by someone else and only adapt it to fit your lesson plan and students' knowledge level. ContextMinds offers search portals where you can find a large number of shared concept maps. For the purpose of the lecture, you might consider splitting a larger map into a series of smaller maps, imitating slides of a presentation. As the average size of human working memory can hold 5 to 9 objects at a time, it might be best to create small maps with just up to 9 concepts. After such a series of smaller detailed maps, you might finish the lecture with a larger map summarizing the whole topic.

Creating the map from scratch during lecture puts quite high demand on your ability to efficiently work with the software. However, the software might make your work much easier by suggesting new concepts automatically. You then don't need to write their names. Instead, you just drag and drop new concepts from the suggestion pane to the map. This feature is well developed especially in ContextMinds. The best way to make it work properly is to combine the approaches by first preparing the map in advance and then rebuilding it from scratch during the lecture. ContextMinds can then also automatically add relationships, so the only thing you need to do is to select and place the concepts into the map.

## Adapting the map to the audience

As said before, it is crucial that the map you present to the students fits their level of knowledge and that it includes links to concepts they already know so that meaningful learning can happen.

The best way to learn how to work with concept maps so that the students can understand them clearly is through their own experience, by encouraging discussion and collaboration on concept mapping during lectures.

## Concept maps for revision or self-study

There are several ways of how students can use concept maps for revision – instead of or combined with classic textual hand-written notes or reading textbooks.

- Passively studying a concept map prepared by someone else

In the best case, that would be a map prepared by the teacher or a map that was created during a lecture, in collaboration of teachers and students. Students might also use other maps publicly available on the web. In that case, it is important that the students are already familiar with concept mapping so that they can recognize a low-quality map or a map that does not fit their needs (even though it is covering the right topic, it might be too complex or too simple) and don't waste time with.

- Passively studying a concept map created by the student during the lecture

Instead of taking hand-written notes, students might take notes directly in the form of a concept map. They might **create it from scratch** even in case the teacher doesn't use concept maps at all. Otherwise, the **teacher might give students a skeleton map** that they can finish during the lecture. Or, in the case of collaborative concept map creation during the lecture, **students might follow the teacher and add the concepts to their own maps**, with an option to place the concepts differently or slightly alter the concept and relationship labels according to their opinion, thus fine-tuning the map to exactly fit their thinking style. Creating the map from scratch while listening to a lecture requires a skilled concept mapper and advanced software like ContextMinds that enables rapid map creation. The remaining two options can be combined: students might start with a skeleton map and then follow the collaborative creation.

That is probably the best option, with highest chance to get students involved and at the same time not putting too high demands on them. It is however quite demanding for the teacher.

- **Students concept mapping on their own, outside lectures**

This can also be practiced even if the teacher does not use concept maps. Students can create their own maps based on textbooks, materials shared by the teacher or their textual notes from lectures. Passive looking at a previously prepared concept map is good for the revision of a topic already known quite well. At an early stage of learning, it is always best if the students try creating the map on their own, as it forces them to actively think, find out answers on how to fill-in missing relations. The students might feel that would be too much hard work and might still prefer staring into a textbook. Practicing concept mapping during lectures or encouraging students to concept map in the form of homework might help to convince them to start concept mapping on their own.

## **Concept maps for homework**

Giving students assignments to create concept maps as homework is a good way to get students involved in concept mapping at the beginning, shortly after they are introduced to it. Similarly, as mentioned above, you can give them an incomplete map to finish, or they can just start mapping from scratch. In both cases, it is important to clearly define the topic and scope of the concept map. The best way is to use a focus question instead of a general topic definition.

Students can prepare concept maps instead of essays, surveys or papers: choosing the topic or focus questions and then presenting the results to the class.

Or everyone can make a concept map on the same focus question. The teacher then checks all created maps and points out errors and misconceptions, eventually showing a “correct” or “reference” concept map in the next class.

## **Concept maps for assessment**

Concept maps can be even used for assessment. Instead of writing answers in free text or choosing the correct answer from a defined list of choices, students can answer a focus question by creating a concept map.

Similarly, as in other cases, the map can be created from scratch or the students can be given an incomplete skeleton map.

Another option is to give the students a blind map. It may contain only the concepts, so the students must link them with proper relationships. The concepts can be placed in advance (see figure 15), or they can be laid out in a simple list – a sort of parking lot for concepts from where the students select them and place them properly.

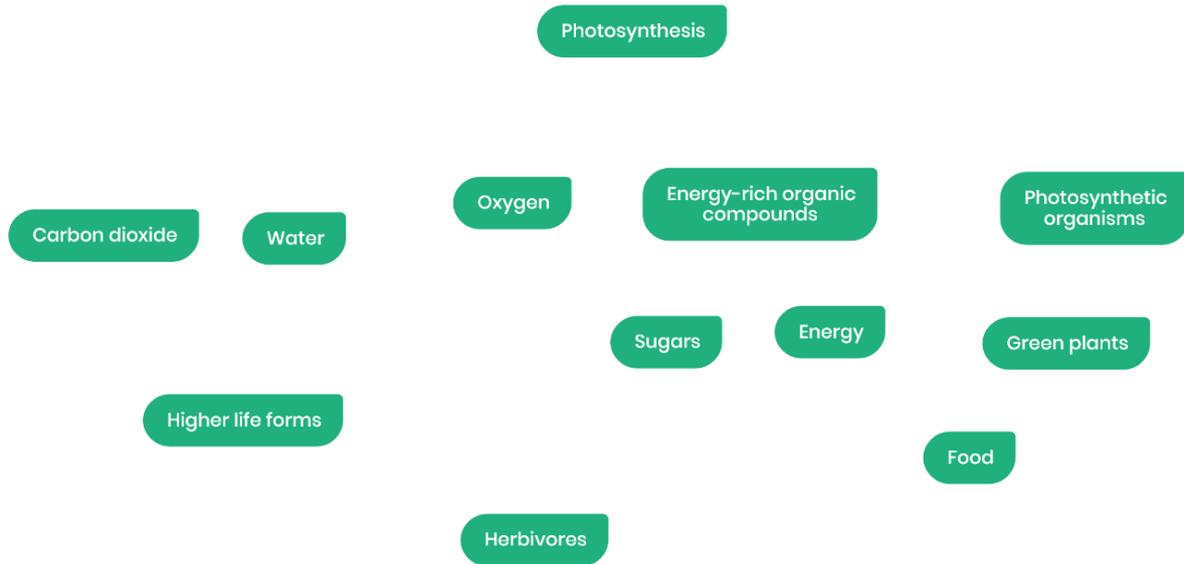


Figure 15: A blind map with unlinked concepts.

Or the map can include the relationships but have concepts without labels – the students’ task would then be to name the concepts properly so that the links would make sense. You can use numbers to fill the blank nodes (Figure 16). It is, however, good to leave at least some core concepts labeled, so the students can understand the intended structure of the map.

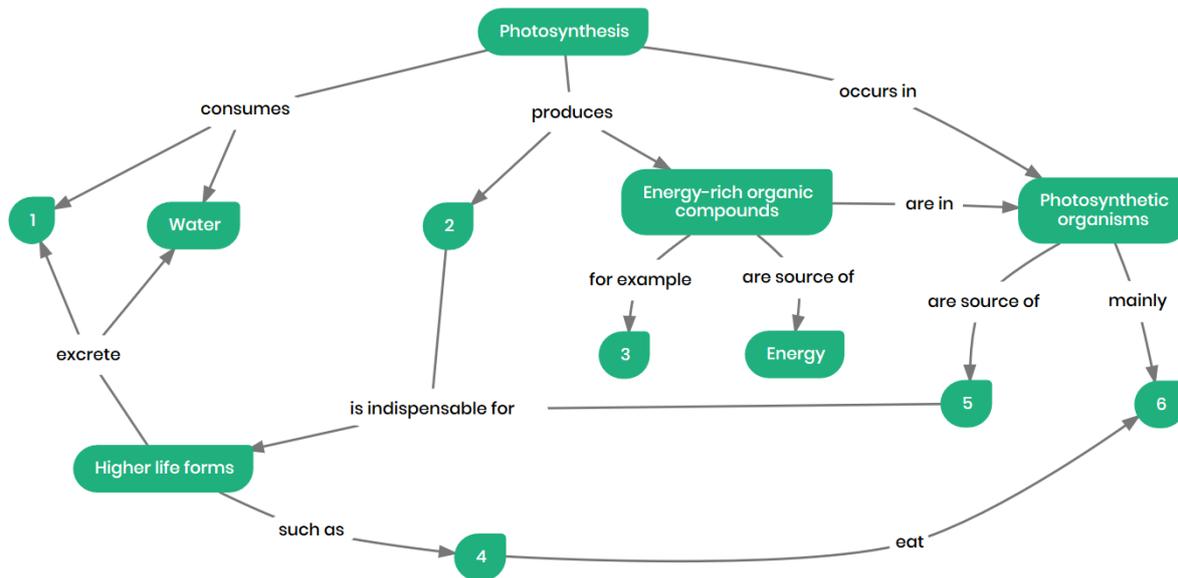


Figure 16: A blind map with blank nodes in place of concepts.

A possible alteration is to have blank relationships between labeled concepts – the task would then be to name the relationships properly.

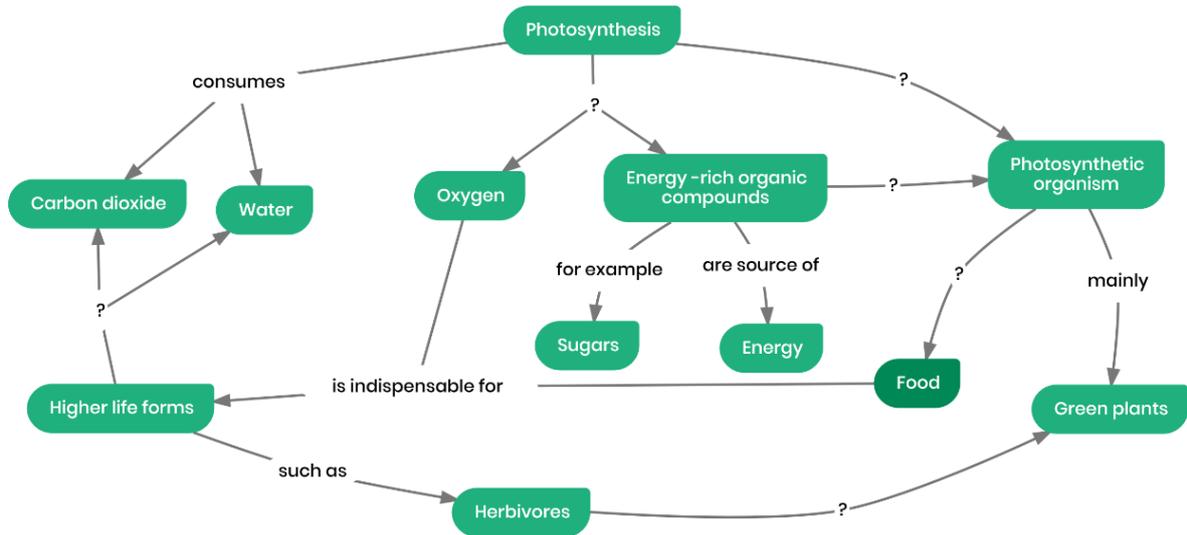


Figure 17: A blind map with unlabeled relationships.

## Concept map for curriculum development

Concept maps are perfect for organizing and planning study programs and topics. Providing a concept map that represents the entire study program is the ideal option how to increase awareness of the importance of the course. Students can directly see what their knowledge at the end of the course should be. It can also represent how the classes are connected so the students can understand them better and be motivated.

Representing the curriculum as a concept map is also beneficial for teachers and study program coordinators themselves because they can evaluate their course and check its coherence.

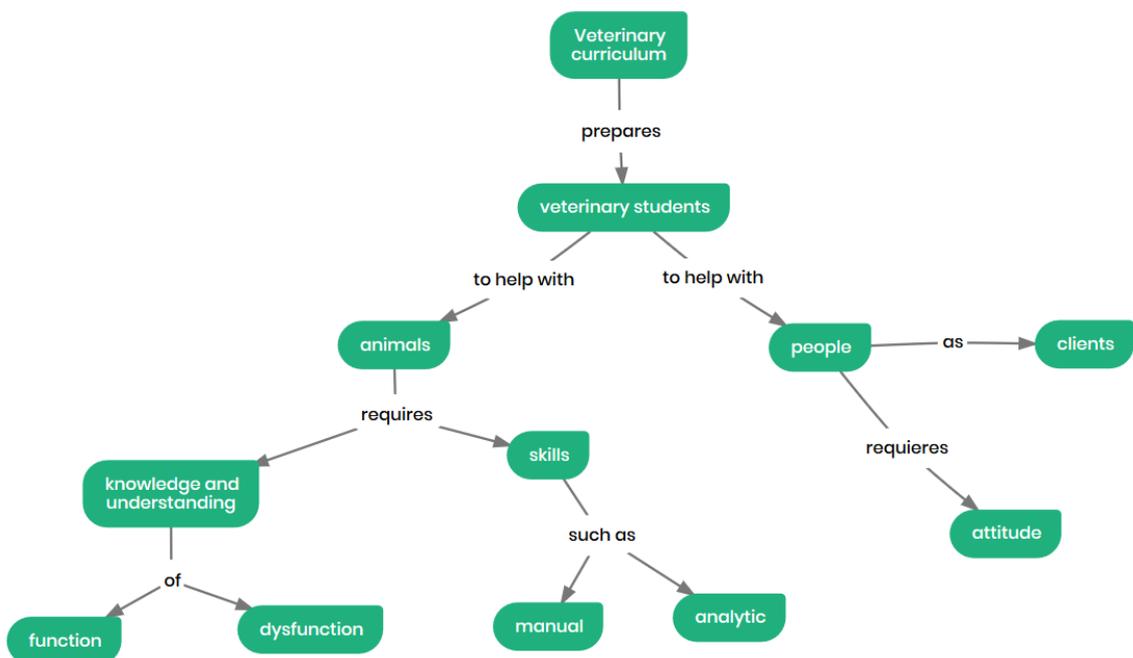


Figure 18: Example of a veterinary curriculum

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