MISCONCEPTIONS aka HOW TO HELP PEOPLE DECONSTRUCT THEIR FALSE THINKING (ON WASTE)

Opening questions for the reader before reading:

- Have you had situations when you, talking to someone about zero waste, notice that you do not come through? Have you ended up with the discovery that they have totally different basic understanding (misconception) about it?
- How do you usually deal with people's misconceptions?
- How do you recognize that you have effectively corrected people's misconceptions?
- What does it take and how long does it take to correct someone's misconceptions?
- How have you found out about your own misconceptions and how did they get corrected?
- How do you feel when someone points out that you are wrong about something and tries to correct that misconception (which they think that you have)?

This chapter is based on the work done by many educational psychologists, see references in the footnote[1],[2]

Misconceptions (or alternative conceptions or intuitive theories) –

- Understandings of certain phenomena based on experience, observation and/or incorrect information that conflict with currently accepted concepts and scientific findings.[1]

What do you think is more effective when talking to someone who has a (zero waste) misconception?

A. Tell them why their idea is wrong and what is the right way.

B. Ask them why they think so, and through questions, slowly get them to question their own ideas and wanting to find more information.

This can also be illustrated by an internet-joke:

Someone told me: "People change their minds if you show them the facts."

I responded with links to different studies: "Actually here are some studies showing that this is not true."

The person responded: "Well, I still think it works."

What does it tell us about the way we often act when our statements are being corrected?

Option A is for sure quicker in terms of passing on the information you want them to have, but if you have read other chapters on learning, you will probably know that it's option B that has more chances of making a change in the way the other person thinks about this issue.

Each of us probably has misconceptions in most of the fields where we are not experts in. We form misconceptions based on our everyday life, from what our friends and family tell us, what things happen to us, what we see happening to others etc. So, misconceptions are actually totally normal; yet they do not help us with the complexity of the world. An important characteristic for misconceptions is that they **rely on perceptual information,** but the mistakes in the logic cannot be found through our senses and perception.

As a very basic example, thinking that the Earth is flat is based on observing the horizon being flat. The knowledge of Earth being round comes from scientific inquiry and, in a way, goes against our first-hand experience of the world. Similarly we cannot know only by observation, what

[1] Verkade, H., Mulhern, T. D, Lodge, J. M., Elliott, K., Cropper, S., Rubinstein, B., Horton, A., Elliott, C., Espiñosa, A., Dooley, L., Frankland, S., Mulder, R., and Livett, M. (2017). *Misconceptions as a trigger for enhancing student learning in higher education: A handbook for educators.*

[2] Lucariello, J., & Naff, D. (2013). How do I get my students over their alternative conceptions (misconceptions) for learning.

phenomenon is lightning – a theory needs to be developed and tested step by step, as well as scientific method needs to be applied to understand that it is electricity. We know that we should wash our hands with soap to kill unwanted germs based on scientific knowledge, as we cannot see germs with a naked eye. So misconceptions form around information, which is hard to understand without higher conceptual thinking, and without empirically tested theory. For example, people can have difficulties understanding why incineration is not a good idea. To them it seems that the waste disappears, the problem goes away and energy is created – this seems like a good thing.

DEVELOPING EXPERT THINKING

One of the keys for correcting misconceptions is practicing thinking like an expert. This means understanding all the steps and details that experts consider when approaching an idea or statement.

For example, you can watch this video and write down your thoughts in two different roles:

A. Yourself as a zero waste expert,

B. As a regular person, who is not familiar with waste management.

Questions to consider:

- What do you notice in the difference between these notes? How does expert thinking differ from that of a non-expert?
- As an educator, how would you talk to the regular person about their thoughts and opinions? How could we get the regular person closer to thinking like an expert?

Some characteristics of an expert thinking:

- Knows, what are the key defining – but often invisible – features of the phenomenon; that is, knows more precisely, what is the essence of the phenomenon,
- Applies formal logic and checks their assumptions,
- Thinks about two things – about the subject matter and **about how they think** – so there is critical metacognitive reflection about one's thinking,
- Is able to inhibit in themselves the urge to make conclusions based on how things "seem to be".

The road towards expert thinking takes time and we need to realise that others might think about zero waste a lot differently than we as the experts. Here one way to get closer to expert thinking and making learners aware of their misconceptions is the productive failure design approach introduced in our *Main principles of teaching*. There is a very nice TED talk on that and expert thinking.

Correcting misconceptions is called **conceptual change**. It's important to know that in most cases we cannot replace misconception with correct conception by simply stating it to the learner (although in some easier cases it can be that simple). Also we cannot make others change their misconceptions – the **willingness to correct them must come from the learners themselves**.

Before we can start correcting misconceptions we need to understand what they are in their core. Are they all similar or different?

Exercise:

Look at these five misconceptions – what are the reasons why such misconceptions appear? In what sense are these misconceptions different?

- Cigarette butts biodegrade
- Burning is a solution for the waste problem
- Tuna is a smaller fish than the whale
- Biodegradable dishes are a solution to single-use plastic
- Some children are just not interested in learning as they are so passive in lessons

How could we help to modify them to more correct conceptions? Do we need the same or different strategies?

TYPES OF MISCONCEPTIONS

Not all misconceptions are created equal. As the roots and reasons why they form can be different, so can their essence and therefore approaches how to correct them, be different.[3]

Inaccurate misconception type – it is incorrect in comparison to the accepted concept, but is in the same 'dimension' or quality.

E.g. all separately collected plastic gets recycled (reality: only a small amount of separately collected plastic gets recycled). The same dimension is the process of recycling.

Incommensurate misconception type – the information relates to a different, incorrect 'dimension' or quality.

E.g. incineration is a form of recycling (reality: in incineration materials are lost and not put back into use like in recycling). The processes are of different "dimensions" in their essence.

[3] Verkade, H., Mulhern, T. D, Lodge, J. M., Elliott, K., Cropper, S., Rubinstein, B., Horton, A., Elliott, C., Espiñosa, A., Dooley, L., Frankland, S., Mulder, R., and Livett, M. (2017). *Misconceptions as a trigger for enhancing student learning in higher education: A handbook for educators.*

Inaccurate misconceptions have two subtypes:

1. **False beliefs** – misconception about a single idea that can usually be expressed in one sentence.

Thinking that all plastic gets recycled vs that only a small amount actually is recycled is an example of a false belief.

2. **Flawed mental models** – one or several flawed ideas or assumptions that are internally consistent with one another, but contradict the assumptions of the correct model. Because of this internal apparent consistency, flawed mental models can be quite difficult to correct.

Believing that the solution to the plastic problem is better collection and recycling could be a flawed mental model, because it mainly consists of the elements of plastic and recyclability, which are internally consistent. Therefore believing that if we improve recyclability and collection, our problem gets solved, but the element of oil extraction and plastic production is not included into the model, which makes it inaccurate in the end.

Incommensurate misconceptions also have two subtypes:

1. **Category mistakes** – when a thing or concept is placed in the wrong category, and thereby inherits the characteristics of that category.

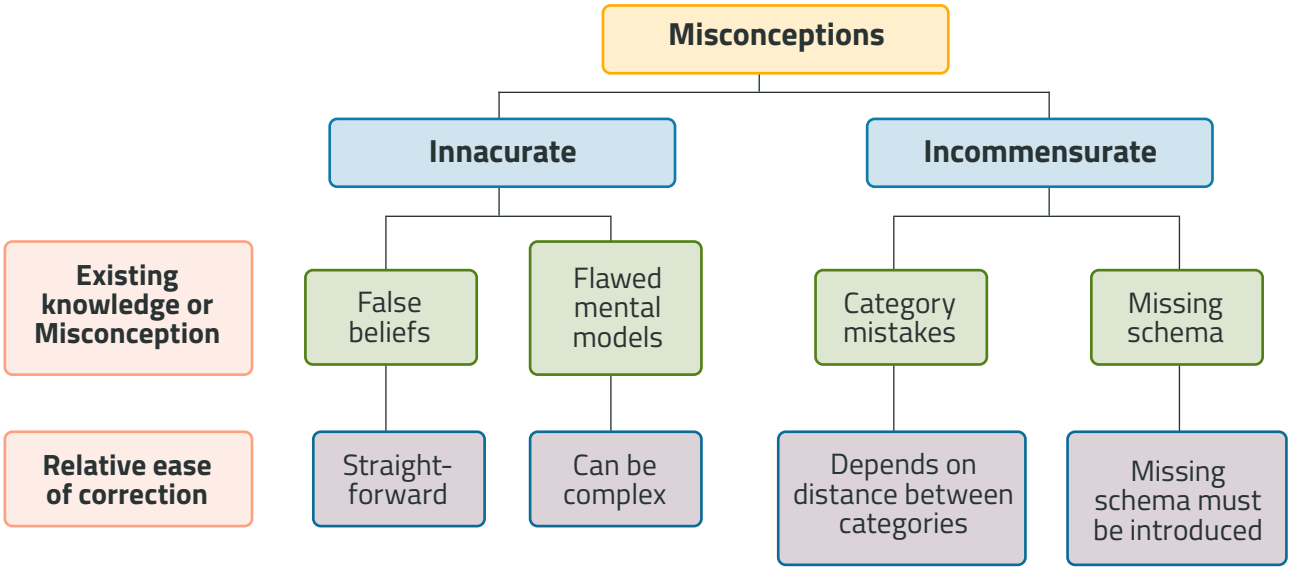
Incineration and recycling are both waste treatment methods, which is their common bigger category. However placing incineration in the same category as recycling would mean that they are both considered to keep resources in circulation, which is not true in the case of incineration.

2. **Missing schema** – putting something into the wrong category, because the right category is not represented in the person's mind. This type of misconception could be especially difficult to correct, as besides identifying that the misconception comes from the person having it in the wrong category in their mind, the right category must be first introduced, with its characteristics, before the misconceived information can be corrected.

For example thinking that bioplastics are a good solution, because they are of natural origin and biodegrade in nature. A whole schema of differences between biobased, biodegradable and compostable plastics is missing, including differences in their composition, production, collection and treatment methods. Another example connected to this is thinking that organic matter will become compost in every condition – there is a missing schema on differences between aerobic and anaerobic decomposition processes and what is actually needed for organic matter to become compost.

Here is a flowchart on the types of misconceptions and their ease or difficulty of correction:

Definiton of four types of misconceptions, adapted from Chi



Graph: Misconceptions model from Chi[4], adapted by Verkade et al[5]

CORRECTING MISCONCEPTIONS

While false beliefs can be corrected quite easily by explaining the right data, other misconceptions are more difficult to tackle. So if the misconception is actually something other than simple false belief, then only showing our correct data won't do much to change the misconception.

The steps for correcting misconceptions are[5, 6]:

1. Us as educators identifying the misconception.
2. The learners recognising their misconception.
3. The learners constructing a new model.
4. The learners using the new model.

1. Identifying the misconception

This can be done by asking open-ended questions. For example, asking to define words "redesign", "reuse", "recycle", "upcycle", "downcycle" and asking for examples from real life. People tend to think they know these terms, but when asked to define them, it often turns out they can be

[4] Chi, M. T. H. (2013). *Two kinds and four sub-types of misconceived knowledge, ways to change it, and the learning outcomes,* in S. Vosniadou, (ed.), International handbook of research on conceptual change.

[5] Verkade, H., Mulhern, T. D, Lodge, J. M., Elliott, K., Cropper, S., Rubinstein, B., Horton, A., Elliott, C., Espiñosa, A., Dooley, L., Frankland, S., Mulder, R., and Livett, M. (2017). *Misconceptions as a trigger for enhancing student learning in higher education: A handbook for educators.*

[6] Lucariello, J., & Naff, D. (2013). How do I get my students over their alternative conceptions (misconceptions) for learning.

quite mixed up. It is always worth asking your participants/listeners even what common terms mean, just to see if everybody actually understands what is being talked about. Any other approach, where learners have to demonstrate their thought process, can also help to unveil the misconceptions.

2. Helping to recognise the misconception

The **learners themselves must notice** that maybe there is a gap in their knowledge, maybe their understanding is different from the scientific understanding. Questions are good in this stage too: asking to explain their reasons for the misconception, why do they think that way? Comparisons are also a good tool in this stage, asking for example people to compare "their" data with the correct one.

3. Constructing a new model

This means finding a better and more sense-making model that can explain the observed facts and which can replace the misconception. The new model should be:[7]

1. Intelligible – learner can understand how it works, we can use analogies, models or directly showing the mechanism.
2. Plausible – it feels true and believable, learners must see how the new conception (theory) is consistent with other knowledge and a good explanation of the data.
3. High quality – besides good quality in scientific standards, the new theory should feel of better quality to the learner and not contradicting their other unidentified misconceptions.
4. Fruitful/generative – useful to the learner, they can put it into practice, we can illustrate the application of the new concept/theory to a range of problems.

4. Using the new model

Since misconceptions tend to be quite sticky in our heads, there should also be opportunities to put the new conceptions into practice – learn different cases, see where this new info is useful and can be applied. There could be a slightly different problem presented where using this new model is needed in order to solve it. This could also help to assess whether the misconception was indeed corrected.

[7] Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science education*, 66(2), 211-227.

SOME METHODS FOR CORRECTING MISCONCEPTIONS

General recommendations:

- Explore and activate preconceptions – for example ask some questions beforehand, to get a sense of learners' understanding of the topic(s) and adjust teaching to that.
- Some of preconceptions may be correct – use them as a bridge of examples to the new conceptions.
- If you present new concepts, then in a way that learners see these as plausible, high-quality, intelligible and generative.
- Help them to become aware of their own misconceptions.
- Help them "self-repair" their misconceptions – ask questions!
- Once they got over their misconceptions, allow them to use their new knowledge, e.g. in debates, to strengthen them.
- Throughout the process: don't rush to tell your own expert knowledge, always ask questions from learners first and allow them to construct their conceptions as independently as possible.

Here are some methods and ideas how different zero waste misconceptions could be addressed.

Bridging analogies

Bridging analogy is the approach of using the learner's already existing correct belief or conception (called "anchoring conception") by "bridging" it to the new conception ("target conception") where the learner has a misconception.

An example in zero waste could be:

Misconception: biowaste and compost are the same, just piling up biowaste is already composting.

Questions to get to the bridging analogy:

What is the end result of composting?
How does the biowaste turn into nutrient-rich soil? What could we compare this process with? Perhaps another example of turning organic matter into "a product" like making pancakes.

1. Anchor example: in order to make pancakes you need to mix the right ingredients (and only food ingredients) and heat them on the stove. You wouldn't add the plastic food package into the pancake dough, and you wouldn't expect pancakes to cook if you haven't turned on the stove.
2. Bridging example 1: compost needs to be "cooked" (prepared) the same way as we use food ingredients to make meals. Biowaste itself is not compost yet.

3. Bridging example 2: in order to make a specific meal, we choose the right ingredients in right proportion and prepare them in the right way (we mix flour, eggs, milk before pouring onto to the pan), the same way for compost, we need to mix food waste with bulky wooden materials to adjust nutrients, moisture and air flow in the compost, which allows microorganisms to do their work, which is needed to get good compost.
4. Target example: in order to make compost, you need to collect it separately, so that you only have organic waste and you need to use the proper technology to degrade it in the way that it makes good compost.

Diverse instruction

Misconceptions can often be a collection of more than one wrong belief, for example a whole missing schema. Diverse instruction means addressing several of them at once. Studies[8] have shown that conceptual change is more likely to happen if we give less examples, but about several wrong assumptions rather than many examples of only one wrong assumption.

An example in zero waste could be:

Misconception: biodegradable plastic is better than regular plastic. It composes of several missing schemas:

- It is made from biomass/plants so it's better than regular plastic (right conception: regardless of the material, single use is still a waste of resources).
- It simply degrades in the environment (right conception: biodegradable plastic has to be collected together with food waste, transferred to composting facility and composted by skilled personnel to fully degrade).
- It's just as good for compost as biowaste (right conception: biodegradable plastic is still plastic and doesn't add value to the compost).

For example: a takeaway food restaurant owner tells you proudly that they are now plastic free – all their dishes and cutlery are from biodegradable plastic. How do you respond?

At first we could express that it is great/makes us happy to hear that they are trying to improve and make steps towards better solutions. And then continue with these questions in a warm manner:

- Why did you decide to make a switch from plastic? Why do you think plastic is a problem?
- Why did you choose this solution?
- Why and how is it better/best solution?
- What is this material (biodegradable plastic) made of?
- What do you think, what will happen to it if thrown away?
- How can we be sure?
- Would you put it into your own garden compost? Why or why not?
- What happens to it in the compost?

[8] Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, 24, 535-585.

Predict-observe-explain model

In this method, an experiment is made to correct a misconception. The experiment doesn't have to be hands-on, it can also be a video or thought experiment.

The first step is for learners to predict what they think would happen. Then the experiment would be done and learners can compare their prediction with the actual result and explain why it is so, why they differ, if they do. This allows learners to become aware of their own thinking and logic.

One version of this method is the predict-explain-observe-explain model, introduced briefly in this short video.

An example in zero waste could be:

Misconception: there is no room in my flat to source separate waste, I don't have room for 3-4 different bins.

Question to be predicted: how much more room do you need if you sorted your mixed waste by fractions?

Experiment: taking that mixed waste (or clean "mock up" waste) and sorting it by fractions, and then putting it into separate bins, which are all just smaller than one big mixed waste bin, showing that because the waste amount is the same, you don't actually need more space, just more but smaller waste bins.

Discussion and explanations.

Cognitive conflict

This means offering the learners new experiences that don't match with their current conceptions, which can lead to conceptual change. Ways to create this:

- Present data to learners that doesn't match their existing conceptions (anomalous data). The anomalous data should be credible and ideally somewhat known from their everyday experience. If possible, illustrate the data with experiments. Use this as a basis for discussion.
- Present texts that introduce a common misconception and then overturn it, and offer the new conception/theory. This would again be the basis of discussion where learners could support their views with the evidence from the text.

An example in zero waste could be:

Misconception: the amount of waste entering a waste treatment facility is the same you can recycle, eg. 100 t of biowaste means you get 100 t of compost, 100 t of packaging waste means you can recycle 100 t of materials.

Presenting data:

100 t of biowaste enters the composting facility, 40 t is sold as compost.

100 t of packaging waste enters the recycling facility, 90 t is sold for recycling.

Basis for the discussion: what happens to the missing 60 t / 10 t?

Biowaste is largely water that goes away during the composting process. Packages are never totally empty, bottles also have liquids inside – liquids are pressed out during the process. Input waste can be wet from poor storage conditions as well, increasing its water content.

Socratic method

Socratic method is one of the oldest forms of learning through discussion. It focuses on revealing the preconceptions of the learner and asking questions designed to prompt the learner to challenge their own assumed prior knowledge. It is a four-stage process that involves:

A. Bringing out preconceptions/misconceptions;
B. Asking clarifying questions to pinpoint the nature of these preconceptions and lead the learner to form their hypothesis or prediction;
C. Testing these hypotheses through further questioning, fact-checking, counter-arguments, identifying contradictions etc. which require the learner to critically evaluate their preconceptions;
D. Reassessing their thinking and deciding whether to accept or reject their preconceptions, predictions and any new information.

The socratic method can be found also from surprising places like pop-culture (for example "Pulp Fiction").

An example in zero waste could be:

1. Bringing out the misconception: "In our city we have a new environmentally friendly way to treat waste: we have an incinerator that burns the waste completely and creates energy."
2. Clarify: Can you explain why burning waste is good? / How burning the waste relates to the issue of shortage of (basically all) materials we use?
3. Testing:
   - How much waste does the incinerator need in order to produce that energy? What if we don't create that much waste anymore (do more reducing, reusing, recycling)? Can the incinerator still operate then?
   - What types of waste are being burned in the incinerator? How much of it is left at the end?
   - What about the energy that was needed to produce those materials, which are now lost in the burning process?
   - Is incineration helping or stopping us to get closer to a circular economy, where materials are kept in circulation and waste amounts are reduced?

4. After these questions the learner can decide whether to accept or reject their original misconception.

Can you find any common traits or characteristics of all these methods?

FREQUENTLY ASKED QUESTIONS

Before reading the answers, think to yourself: **how would you answer them?**

1. In zero waste work we often have only very little time to meet with people (one business meeting etc), where we don't have time to go through these exercises. What can we do there?
2. We both have one-to-one meetings and larger group presentations/sessions in zero waste work. It can be harder to work with misconceptions when you have a big group of people, each of them with different misconceptions. How can we deal with this multitude of misconceptions?
3. In zero waste there are not many misconceptions, or they are actually quite easily corrected with the right data. Shouldn't we focus more on giving people the correct knowledge on zero waste?

1. **In zero waste work we often have only very little time to meet with people (one business meeting etc), where we don't have time to go through these exercises. What can we do there?**

   The hard reality is that we cannot speed up the way the brain functions/processes new information, even when we would like it to and have little time and want to get more done in that short period of time. Correcting misconceptions does take time and when we are given only short time, what we can do is at least get a better understanding ourselves of the kind of misconceptions people have, pose some open questions to them and make them wonder if there is perhaps more to discover/know, so that they would be interested in meeting you again and/or digging into the topic themselves more. That's why it's good if we already have done some pre-communication with them and gotten to know what exactly their misconceptions are, so that in the meeting we can already go to building new conceptions. In every situation we can decide to ask questions instead of telling the right answer (which is something that often comes almost automatically to us as zero waste experts) – while it could make us feel better that we shared our wisdom (and could listen to our beautifully organized knowledge), a question will help the other person much closer to discovering that truth themselves – as building and organizing the correct knowledge in their own mind is actual learning. But this also means not appearing or sounding passive-agressive and attacking, but rather curious questions with the sense of how we can solve this contradiction of views together.

2. **We both have one-to-one meetings and larger group presentations/sessions in zero waste work. It can be harder to work with misconceptions when you have a big group of people, each of them with different misconceptions. How can we deal with this multitude of misconceptions?**

   Misconceptions tend to be quite common, meaning people often have similar misconceptions in one broader topic (like zero waste). So even if you think only some people have one particular misconception, it could easily be that others also have it, they just haven't expressed it verbally or haven't even realised that they think the same way. So picking one misconception to tackle could still benefit many people in the audience.

   When you can identify several different misconceptions among the people, then one possibility is to tackle them together, if they are similar in their logic. For example, thinking that the washing process of reusable dishes takes a lot of energy and thinking that biodegradable plastic dishes are a solution are part of the same misconception where people don't realise the environmental impact of the whole lifecycle of the product. So it would be a possibility to group some misconceptions and focus on their common trait and address that to your audience.

3. **In zero waste there are not many misconceptions, or they are actually quite easily corrected with the right data. Shouldn't we focus more on giving people the correct knowledge on zero waste?**

   It could be true that some zero waste misconceptions can be easily corrected by showing the data. But what might for some be a missing piece of data (not knowing the actual recycling rate) could be a whole missing schema to the other (not understanding what recycling even is). Without getting to know exactly what it is that the person doesn't know or has misconception on, we cannot approach it the right way. The main question is perhaps, how do we know that we corrected someone's misconceptions? If we cannot check if people actually changed their minds after we told them the right info, then how do we know that they accepted our facts?

   Maybe sometimes people's inactivity towards zero waste could be not because of not wanting to act but that in the end they have deep hidden misconceptions about it?

Ending questions for the reader to reflect upon:

- What parts in this chapter were most confusing or difficult for you to understand? Why do you think it was so?
- Can you think of any examples how to implement these practices in zero waste work?
- Do you think it's worth approaching people's zero waste misconceptions the way described in this chapter? Why or why not?
- What do you want to take with you from this chapter?
- If and what next steps do you want to take in your work regarding this topic?
- What do you want to know more about?