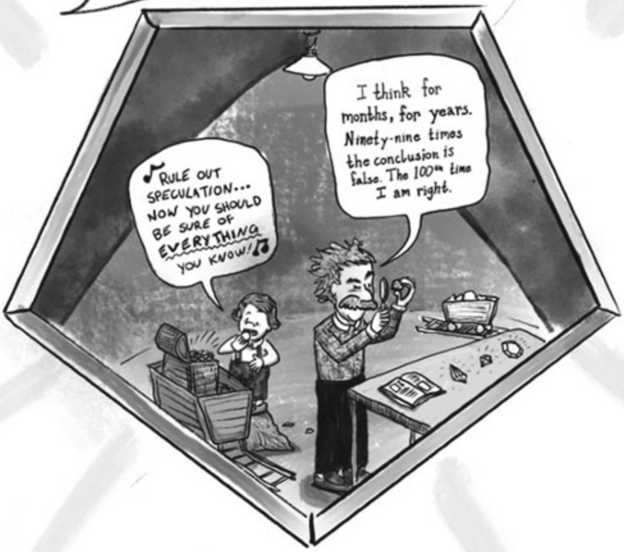
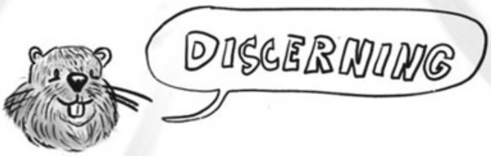
Chapter 4
What do we trust?
Evaluate & Reflect





Chapter 4
What Do We Trust?

4.1 Gullible Consumers or Discerning Users?

In the Information Age, students, teachers and learning communities are at risk. The question of what to trust is central throughout formal and informal education. From stranger danger to fake news, from misleading websites to scam journals, questions of trust are tangible. This partially accounts for the frequency of use of the term 'critical thinking' in education. Of course, it is not only students that are challenged by fake information in the Information Age—educators also have to make sense of competing educational perspectives, such as the debate about whether comparative testing facilitates or hinders learning. Information that displays markers of credibility cannot be taken at face value: there are many errors in peer-reviewed journal articles, even in journals with tight quality controls [2].

Another, more buried, aspect of trust concerns the educational perspectives that we hold to. Why is it that some educators lean towards modes of instruction that are highly directed, some towards those that are open-ended, and others somewhere in-between? This too is a question of trust in regard to pedagogies of choice, and determines where we put our concerted efforts, what we can and will achieve as individual teachers, as a whole school community or as a system. But why do some hold a more objectivist rationale, while others are geared towards social constructivist approaches to education? What we trust also determines the types of controversies and arguments we enter into, as well as the resource allocations that affect our students' learning. Building on the core characteristics of MELT as depicted in Chap. 2, and the diversity of its use as shown in Chap. 3, the purpose of this chapter is to use the MELT for reframing the competition between different educational perspectives and dealing with some trust issues. My aim is to show how each perspective may complement the other through the MELT.

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In the following section, I present a vignette about Tara, a Year 8 student who engages with a canonical science experiment and declares ‘I told you science is stupid ‘cause you don’t know if you’re right.’ There are good reasons why Tara declares science to be stupid, and something not to be trusted. This chapter applies the MELT in order to help you ask, ‘what do I trust?’ It is a challenge to suspend judgement, or at least to give licence to the possibility that educational perspectives other our own may have some merit. We will use the facets of MELT to interpret Tara’s story and consider two facets in detail that are crucial to the issue of trust: *evaluate and reflect* and *analyse and synthesise*. We will then use this interpretation to broaden our look across the educational landscape, and turn the question of this chapter to ‘why do we distrust other educational perspectives so much?’ with consideration for the implications of what we trust and distrust.

The story is called *Shrink*. It describes a situation where I engaged with Tara and her work partner Shannon as a Participant Observer [3] in another teacher’s class.

4.2 Shrink

By the time I sit behind Tara and Shannon on the experimental bench that runs along the rear wall, Mrs Stuebalm is already asking the class a recollection question: ‘What happens to a gas when we heat it?’

‘Expands,’ exclaims one of the boys.

Tara calls out, ‘Matures.’

I wonder to myself why Tara uses that word.

‘This afternoon we are doing another experiment, and I want you to predict what will happen,’ says Mrs Stuebalm. ‘What do you think will happen if we heat a solid?’

‘Expand,’ says one of the boys near the front.

‘Yes. A very good word,’ commends Mrs Stuebalm.

The boy throws his chest out.

‘Metal burns and shrinks when you heat it,’ adds another boy

Mrs Stuebalm seems to avoid his statement, and immediately asks the students to start writing their predictions in their exercise books.

Mrs Stuebalm refers to a diagram depicting a metal ring. The ring’s inside diameter is slightly smaller than the outside diameter of an accompanying metal ball.

She explains, ‘What you’re trying to do is put the ball through the hoop. You need to be careful, because you could burn yourself. Decide what to heat, the ball or the ring. You have to push it through the ring.’

Tara collects the equipment and sits down next to Shannon at their lab bench. They light the Bunsen, and start heating the ring. Soon, Tara lowers the ball through the hole in the ring, and says, ‘We did it!’

She looks very satisfied at their success.

Suddenly, Mrs Stuebalm calls out, ‘OK everyone, pack your equipment away. Write down the equipment and tell me what happened to your ball and ring.’

I return to Tara to ask her, ‘What was your prediction?’

'Metal would burn and shrink… and that's what happened. It shrinks to let the ball through.'

I'm caught by surprise, but Shannon rescues me.

'No it doesn't. It expands.'

'No, the ring shrinks,' retorts Tara.

'It *expands*.'

'It *shrinks*, because the ring becomes thinner and thinner, until the ball gets through,' explains Tara, getting extremely frustrated with Shannon's thinking.

Shannon is also annoyed with Tara, and retaliates, 'The hole has to get bigger to let the ball through, so the metal must *expand*.'

Tara and Shannon call in Mrs Stuebalm, but the conversation goes round and round in similar circles.

Returning to the front, Mrs Stuebalm asks the class, 'What happens to the solid when it's heated?'

'Expands,' someone calls out.

Mrs Stuebalm nods confirmation.

Shannon whispers to Tara, 'I *told* you.'

Tara sits quietly, looking annoyed. I return to her to try and understand her point, and she continues her explanation: 'I mean it shrinks outwards. Like, the metal inside shrinks towards the outside.'

'You're saying the actual metal bit gets smaller?' I probe.

Tara nods.

'What actually happens is the metal expands and moves out,' I explain.

'I told you!' triumphs Shannon again.

Tara grows even more frustrated, but presses on: 'The outside expands to give the inside room to shrink… see, I said science is stupid, 'cause you don't know if you're right.'

4.3 MELT Analysis of Shrink

In order to consider the question 'what do we trust?' I begin by unpacking *Shrink* through the lens of MELT, considering each facet and focussing especially on *evaluate & reflect* and *analyse & synthesise*. Then, I use *Shrink* as a reflective surface from which to gain perspective on three theories of education.

As with the earlier stories in this book, *Shrink* provides examples of students employing all six facets of the MELT. The scenario in which Tara and Shannon find themselves is a very prescribed and ostensibly simple lab task (see Fig. 4.1). The lab is intended to demonstrate, unequivocally, the canonical idea that 'metals expand when you heat them'. The trouble is that Tara constructs a counter-intuitive interpretation of the results, even though she makes the same observations as Shannon and others in her class.

While this scene is set in a science context, the ramifications are relevant to the ways in which students develop an understanding of core concepts in any subject or discipline. Any student may guffaw, 'I told you this subject is stupid. You don't know

Fig. 4.1 Two students heat a metal ring, so that its expansion allows a metal sphere to pass through it

when you're right'. And the issues for student learning are immense when educators try and fail to help students gain fundamental understanding.

Tara was working hard conceptually to make sense of the practical, and even though the classroom consensus was that 'metals expand when you heat them', Tara would not be persuaded. When I interviewed her one month later about this incident [3], it turned out that she had some good reasons to think metals shrink when heated. She had previously watched her dad soldering, and noted that the soft soldering metal 'shrinks in'. Likewise, throw an empty aluminium can on the fire, she said, and it shrinks. While both these observations are better explained by other concepts (capillary action and chemical change, respectively), I could see that she was basing her current observations on her past knowledge, and that she was striving to make sense of the phenomena. Tara didn't just acquiesce to the classroom consensus or the curriculum; she was willing to challenge both based on what she perceived to be relevent experiences.

In that willingness to challenge the prevailing classroom knowledge, she epitomised the sort of student we are striving to educate—not a gullible consumer of facts, but a discerning user and generator of information. If we are concerned about our students blindly accepting clickbait headlines and 'fake news' by default, we also need to be concerned about how they deal with things that just don't add up for them in our curricula. Tara judged the classroom content, and her verdict was 'science is stupid'. It turned out that she was partly right, in that the experiment, used in science classrooms for a hundred years, is deeply flawed in its design. That the equipment is constructed in such a way as to provide ambiguous data, making it open to interpretation, has been known for some time [3].

All the facets of MELT are present in this story and, as pointed out in Chap. 2, this seems to be typical of even slighly complex learning activities. Even though the location of the lesson on the *continuum of learning autonomy* was *prescribed* in terms of aim, method and final answer, Tara demonstrated something unique in terms of her learning autonomy when engaging with *evaluate & reflect* and *analyse & synthesise*. *Shrink* involved a prescribed practical which was designed to confirm canonical knowledge. However, the complexities and potential sophistication of student engagement with the practical are laid bare when scrutinising it from the perspective of MELT's six facets and autonomy.

Embark & clarify: in the context of the learning topic, the students knew they were doing something concerned with heating solids. The teacher, Mrs Stuebalm, intended for students to learn or confirm that metals expand when heated. Perhaps students other than Tara left the class feeling that they had experienced, constructed and agreed on a scientific 'fact' about metals. And in many ways, Mrs Stuebalm provided a wonderful learning environment, managing the practical risks (naked flames, red-hot metals) and allocating time for an experiment, despite the packed curriculum. As such, the lesson was an ethical and moral endeavour which socialised students into the conventions of science in a way that they could engage with.

However, there is an enduring question for education in this story: how clear was the lesson's purpose to the students? It is difficult for teachers to provide a sense of purpose to students engaging in a series of learning activities across terms and years. If students can't see connections between different activities or develop a sense of purpose, what are the implications for their learning?

Find & generate: the data generated in this practical came from visual observation—primarily, students observed that the ball didn't fit before heating, but did fit immediately after heating. All students 'observed' that the ring's inside diameter grew larger, and Tara and Shannon interpreted this observation in contradictory ways. However, there were no measurements of the ring's actual dimensions, partly due to the dangers of measuring a red-hot ring and the difficulty of obtaining the equipment needed for accurate measurements of the ring's diameter.

Organise & manage: this practical was very quick to complete, and one where you could imagine students having the time to think about its implications. However, for the sake of presenting a succinct story earlier, I didn't mention that the students actually performed several heat-and-expand practicals back-to-back, including one involving liquids, and that these practicals required time to set up, conduct, pack up, clean up and write up. As in *Parachute*, students' ability to develop deep concepts was determined to some extent by their ability to *organise & manage*. This classroom reflected a packed curriculum which, for some students, seemed to impede learning for the sake of coverage.

Communicate & apply: the girls followed a prescribed practical structure to write up their experiment: aim, equipment, results and conclusion. They were not required to draw a diagram, even though a before-and-after diagram would have captured some of the complexity of their thinking. The ongoing communication process was vital to Tara and Shannon's ability to consolidate understandings, and here it was their disagreement that sharpened what they understood to have occurred. Throughout the practical, Tara applied her previous knowledge to the task, making observations based on that knowledge. Her observations and inferences supported the application of her personal theory that *metal shrinks when heated.*

4.3.1 What Did Tara Trust?

Evaluate and reflect: there was little class time to reflect, but as a participant observer in the classroom [3], I had that rare opportunity to interview Tara and Shannonn after the passion of the classroom evaporated. When reflecting on this practical one month later, Tara still thought she was right, and that the classroom science didn't make sense. Her evaluation was quintessential of personal constructivist thinking, and it is rarely so evident as in this account that a student is constructing and weighing up knowledge: 'I said science is stupid'. It may be that the classroom knowledge with which she was presented made her feel stupid, as it didn't fit with her previous experience. Perhaps it unsettled her that self-reflection and attempts to self-correct were of no help 'cause you don't know if you're right.' There is a sense of frustration created by self-doubt. Not only could she be wrong in science, but she would not know that she was wrong, even when she spent time trying to unravel *why* she was wrong.

Analyse & synthesise: everyone, including Tara, inferred that the hole grew larger because of the observation that the ball fell through the hole at the time the ring was heated. However, Tara's theory-laden observation ('it shrinks inwards') led her to strengthen her theory that metals shrink when you heat them. Her classmates considered her to be wrong, even though her analysis made sense in the context of her prior knowledge and her observations. However, instead of being steered into self-correction like the students in *Place Value*, Tara ended up in frustration that you 'never know when you're right'. This is partly because the practical was prescribed in terms of content knowledge, understanding and procedure, with no room for any understanding other than the science canon. Such an approach makes sense insofar as we don't really want students to develop a belief that metals shrink when heated. However, Tara reacted against the correct answer because it conflicted too starkly with the theory she had built for herself.

Tara's analytical thinking was shown in her claim that 'it shrinks outwards. Like, the metal inside shrinks towards the outside.'

'You're saying the actual metal bit gets smaller?' I probed, and Tara nodded.

'The outside expands to give the inside room to shrink.'

Tara's juggling of 'outside' and 'inside' shows that she was considering the width dimension. If one thinks of width, then since metals expand when heated, they would expand in all directions, outwards and inwards. That would make the hole smaller. Because the hole got larger, the opposite must be true: metals shrink to create a bigger hole.

Tara demonstrated ingenious, creative and discerning thinking here to craft her inference based on her observations and prior knowledge. Too bad the class had to pack up, debrief quickly and move onto the next topic. Imagine if the teacher had asked the students to design another experiment to show their ideas, giving them the chance to test some of these or at least think them through. What is a pity is that Tara was thinking in terms of *analysis & synthesis*, but her teacher failed to reward these cognitive skills. For a student engaging in analysis like Tara, science then becomes a 'belief-based subject' in which she should follow the mandates of the teacher, and that such emulation is the only satisfactory way of operating when learning in the classroom. How do those of us with educational responsibilities balance the need to teach students correct content knowledge with the fact that their analytical thinking may sometimes lead them to conclusions which contradict the curriculum? This is another form of the question 'what do we trust?', because what we prioritise indicates what we trust and value.

Within the framework of Bloom's Taxonomy, the knowledge that metals expand when heated is fundamental to students developing an understanding of *why* metals, liquids and gases expand when heated. This is connected to a fundamental theory of matter (called 'kinetic theory') that is often taught in the first year of high school. Without a fundamental understanding of this theory, it is impossible to apply it correctly. Tara could have been guided to consider 'What will happen if you heat the metal ball?' If she had made a prediction consistent with her existing ideas, she would have said that the ball should pass through the ring, since it would shrink when heated. And on observing that the ball did not pass through the ring, she would have been challenged by the phenomena. However, there was insufficient time for this to happen. In terms of the teacher picking up Tara's fundamental error, Mrs Stuebalm did hear Tara's idea. But instead of engaging with her, she proceeded immediately to the front of the room to facilitate a classroom conversation in which the only idea discussed was that metals expand when heated.

Student evaluation, even though hierachically located at the top of Bloom's old taxonomy [4], and second from the top in the new taxonomy [5], acctually is a frequent and recurrent necessity of sophisticated thinking. Evaluation occurs almost always when students are formulating knowledge by internally processing data, information, details or facts. Some of the students in the class depicted in *Shrink* already had the knowledge that metals expand when you heat them, while some may have barely noticed what happened in the practical and just adhered to the teacher's explanation. There may have been some students who had never heard about thermal expansion, but managed to observe the data and construct a phenomena-based knowledge that metals expand when heated. Others may have arrived at the correct conclusion by tuning into the class discourse, relying on the social context, including spoken and written language. Shannon and I were working hard to help Tara comprehend our knowledge, and were using a lot of language and pointing to do so, but Tara's prior knowledge and theories rendered our words senseless to her. She personally constructed and consolidated something that had to make sense to her and, fortunately, she would not acquiesce, because acquiescence would show that she had given up on sophisticated learning in science.

Even in the very simple learning activity of *Shrink*, the empirical substance of which took less than five minutes, learning was very complex and the thinking required to engage with the phenomena of metal and heat was sophisticated. Section 4.5 shows how the multifaceted thinking in *Shrink* renders the perspective of any individual learning theory incomplete, and not to be *fully* trusted to guide the realities of learning and teaching. First, three major theoretical orientations to teaching and learning are summarised and then used to provide perspective on *Shrink*.

4.4 Three Theoretical Orientations to Learning: Objectivism, Social Constructivism and Personal Constructivism

As in most areas of human endeavour, the field of education is characterised by fierce debates about theory. Such debates are necessary: ideally, the theories which provide the best explanation for phenomena become the most popular, allowing disciplines to progress. In the sciences, the 'fittest' theory is the one which is best able to predict phenomena in advance. The scientific enterprise can appear to be frustrated when two long-lived theories, such as relativity and quantum mechanics, fail to connect or to generate compatible predictions [6]. However, some scientists believe that such incompatibility is not a concern, and that each theory is a useful tool of the mind that makes powerful and useful predictions about phenomena that have stacked up over time [7]. For others still, such a clash suggests that both theories may be inadequate, and some deeper theory may be needed.

There are many ways to arrange theoretical orientations in education, and one way of organising them is into objectivism, personal constructivism and social constructivism, three enduringly relevant theoretical perspectives.

Objectivism

Objectivism has as its root a noun, 'the object' [8] which is pre-eminent and must be studied rigorously so that scientists can slowly, progressively and communally reveal an underlying objective reality. A basic tenet of objectivism is that communities of researchers can be confident that, by utilising certain methodological standards, they develop increasingly accurate knowledge about phenomena in the world [9]. A parallel term is 'positivism'. Some say that objectivism was the 'default epistemology' for teaching in Western schools up until the 1980s because it was the only epistemology available traditionally [10].

Objectivism is based on the paradigm that knowledge and truth exist outside the mind of the individual. As such, knowledge and truth are 'objective' not subjective [11]. A teacher or instructional developer who uses a design model based on objectivist thinking analyses the conditions which bear on the instructional system (such as content, the learner and the instructional setting). She uses the analysis to design and prepare the learning environment so that it achieves the intended learning outcomes [12]. Objectivism is typically tied to didactic modes of teaching and learning, like rote learning. It is also tied in with behaviourism [11] and the type of cognitivism that employs a one-to-one correspondence between content and what is learned [13]. Direct Instruction and aspects of national assessment regimes are strongly influenced by objectivism, as is much online learning design and, curiously, the implementation of 'constructive alignment' [14]. 'Curious', because the word 'constructive' was coupled with 'alignment' to connote a constructivist orientation [14]; however, in use, the phrase often boils down to mean 'curriculum that is well structured to achieve its intentions'. The quote above about 'default epistemology' is close to the mark; teachers who haven't consciously thought through their own 'epistemology' or theory of learning will often work from the default setting of objectivism.

Personal Constructivism

Personal constructivism involves internal cognitive processes that build conceptual understanding, based on the foundations of a student's prior knowledge. Learning is a dynamic process, and the way in which learning happens is mediated by internal factors like language, culture and social context. Some personal constructivists see all learning, including research, as a process of trying to ascertain and approximate the nature of objective truth, while others believe that truth itself is internally constructed and does not exist outside of a learner's mind [10, 15, 16].

Social Constructivism

Social constructivism pertains to learning that is co-constructed through interpersonal mechanisms, especially through forms of communication like language. While it is conceivable that a social constructivist may believe in an objectively real world in which we can construct a viable (but never true) understanding, most would hold that the world only is 'real' insofar as individuals or groups of individuals understand it to exist [17, 18].

4.5 Understanding the Three Theories Using the Example of Shrink

Shrink is one example in which a teacher employs Direct Instruction using a prescribed practical to engineer understanding of content. All three theories in 4.4 may shed insight into this one practical. One probing question is 'Why did Tara and Shannon make the same observations, but produce such different explanations?' Their analysis was based on different starting points, including their prior knowledge and experience. In science, the dependence of observation on theory has been discussed for a long time [19]; often, we see what we expect to see. However, in this practical, the girls make the same observation that the ball goes through the ring, and both reason that the hole, therefore, got bigger. Then Shannon says, 'The hole has to get bigger to let the ball through, so the metal must *expand*.' Metallic expansion, however, results in a greater volume and surface area of metal. This is the opposite of most experiences with holes, where to expand a hole, we must take something away. If you have a hole in a wall, and a picture plug is too big to go in, you get a bigger drill bit and take away more of the wall. The analysis made by Shannon, Mrs Stuebalm, the rest of the class and me represented a consensus, but it was not in keeping with our general knowledge of holes. That 'metals must expand' may have been for some a recall of the science canon or just a commonly known 'fact'. Others' analyses may have been deductive rather than inductive: 'metals expand when you heat them. We heated the metal ring, so the metal expanded to make the hole bigger.' What type of reasoning was this experiment, designed in the 1900's, designed to elicit? [20, 21].

4.5.1 Objectivist Perspective on *Shrink*

From an objectivist perspective, Shannon appropriately apprehended the intended lesson of *Shrink*, but it is not clear whether the experiment merely confirmed her prior knowledge, or whether she learned something from it. The lesson featured a very clear design pathway intended to lead students to the conclusion that metals expand when heated, a concept that is experienced, talked about between partners, written down in lab books, and discussed in a whole-class debrief. Like Shannon, most students found it easy and efficient to follow the lesson's designed logic.

Concrete and shallow understandings are often the forerunners of children's capacity to think abstractly. It is beneficial to have correct knowledge which concurs with the experiences of the real world, and this provides students with confidence. When they are able to remember facts efficiently, students find it easier to get into a 'learning flow'. Such a state of flow is hard to enter when students have to work things out from first principles each time. Loading up the long-term memory with a host of relevant knowledge and vital concepts is extremely expedient for learning, and this resonates with the children's willingness in *Place Value* to chant together, to rehearse knowledge in order to develop stronger recall. Many students across formal education ask to be told what to learn, so that they know 'what to do'. Some treat this process as mere spoon-feeding, but the desire and capacity to emulate are common in human evolutionary experience, and frequently reflects the way human minds work when learning.

Moreover, certainty in *what* knowledge is needed is something that many students desire and request. Students feel more confident and less afraid of learning when they understand which knowledge they should prioritise. While learning, students don't know where they are going knowledge-wise, and therefore want an educative presence to guide them. Our online and virtual environments provide much opportunity to test and correct student conceptions, such as Tara's, and lead them into the canon of each discipline.

From an objectivist perspective, a one-to-one correspondence between what is taught and what is learned is the ideal, and this is most likely to happen if students attend to the lesson and the teaching material is well structured, with minimal distracting elements. Students acquire a whole lot of 'misconceptions' through play and discovery learning, and these conceptualisations tend to be resilient into adulthood. Furthermore, child-determined play fails to address many concept-based aspects of modern learning, and so time spent 'learning through playing' needs to be strongly facilitated.

4.5.2 Personal Constructivist perspective on *Shrink*

From a personal constructivist perspective, Shannon's prior knowledge was in keeping with the idea promulgated in class, and so her notion was conceptually reinforced, resonating with her understanding. Tara should have experienced a dissonance between her prior knowledge and what happened with the ball and ring as designed by the experiment. That she didn't experience dissonance showed that her prior knowledge was resilient, and that it became the lens through which she made observations. Frequently, prior knowledge is not replaced by canonical knowledge, but students do learn to give the correct answer at times, even if they do not understand or believe the answer. For example, adults tend to maintain childhood conceptions of the phases of the moon, even after correctly answering multiple-choice questionnaires on moon phases when in school [22].

The metal expansion practical was unintentionally designed in a way that allowed for alternative interpretations, depending on students' starting knowledge and experience. Tara's interpretation was sensible and viable, and it would have been educationally useful if she had been given opportunities to further test her concepts using predictions about phenomena and data. Over time, she may have found internal inconsistencies in her understanding, especially if she had encountered dissonant experiences, such as the ball failing to pass through the ring when the ball itself was heated. In that case, she might have formulated new ideas in keeping with the scientific concept that metals expand when heated. However, these would have been based on her old ideas, which are often resilient [23] and may have ended up being the ones she remembered in the long run.

Through its ambiguous design, this practical allowed Tara to reinforce her prior concept. In the future, this practical should be redesigned so that it provides unambiguous data. For example, such a redesign could involve cutting the ring so that it had a gap, which would lead to the hole shrinking when heated, as a result of metal expansion of the ring's width, where not only would the outside diameter increase, but also the inside diameter would decrease [3].

Eliciting student prior knowledge that is in contrast to the canon can prove to be counterproductive. Sometimes, the students are not consciously aware of their understanding until they are asked to articulate their thinking. Once their understanding is brought to the surface of consciousness, students' concepts may become more resilient, or they may be defensive of their own ideas [24]. Even approaches that pay careful attention to conceptual traps, misconceptions and blockages, such as Threshold Concept-based design (see Chap. 5), may not overwrite past knowledge. Research in the area of student development of misconceptions has shifted from perturbing students with 'discrepant events' [25] to encouraging students to place their concepts and newly introduced concepts side-by-side and contrast them [20]. For example, Mrs Stuebalm could ask Tara to predict what would happen to the metal ball when it was heated. If the observation that the ball would not pass through the ring perturbed Tara, but she still did not agree with Mrs Stuebalm's concept, the teacher could ask Tara to compare and contrast 'expand' and 'shrink'.

4.5.3 Social Constructivism on *Shrink*

From a social constructivist perspective, Tara had limited opportunities to construct understandings together with other students, with the teacher or with the whole class. If the social environment had been more clearly thought through, maybe Tara would have come to share the consensus concept, or maybe she would have convinced others of her idea in the short term. Tara showed evidence of previous social interaction—sitting around a campfire with empty aluminium cans placed in it and watching her father weld. This social interaction reinforced her idea that metals shrink when heated. Only well-engineered social environments would have a chance of changing this, and even if Tara were to be exposed to such an environment, there is no guarantee that her new ideas would line up with the science canon. Definitely, there should be more opportunity to deconstruct the experiment and find flaws in it, such as the ambiguous observation data, where 'hole gets bigger' has two opposite, but viable, possible inferences. A preference would be for Tara to design, in partnership with other students, further follow-up experiences in which students made predictions about metal and heating.

Some of the experiences inside the classroom reinforced Tara's idea. When she commented that gases 'mature' when heated, she was not corrected by the teacher. However, as with *Place Value,* the lesson was designed to let students predict and then maybe self-correct through observation, and so Mrs Stuebalm refrained from correcting Tara's early predictions. Therefore, the teacher subtly endorsed the relevance of chemical change for student thinking about observations early in the class. Moreover, another student made a prediction which may well have influenced Tara later: 'Metal burns and shrinks when you heat it'. It may be that this reinforced Tara's existing thinking or it brought back to mind her experiences with aluminium cans around campfires, legitimating the idea that metals shrink.

Future classes would need much more time for negotiation of ideas, preferably with small group presentations on the different major concepts, as well as time for a class debate. If students were encouraged to prepare their points with diagrams and evidence-based arguments, this would emphasise that learning and rational argument are more important than repeating the 'correct' answer. And canonical ideas would probably prevail if this environment were skilfully facilitated by the teacher.

4.5.4 All Three

The issue of whether each student trusts the teacher, their own rational thinking or the social discourse is an important one. Objectivism, personal constructivism and social constructivism each provide a different basis for teachers, parents, administrators and researchers to understand, plan for and determine how to 'measure' learning. From the MELT perspective, all three theoretical perspectives are pertinent and valid. All three can inform the learning that takes place in classrooms [18]. As we saw earlier, theoretical purity is not the default in the sciences, with competing paradigms such as relativity theory and quantum mechanics enduring together.

Instead of being used to direct educators into a narrowed perspective, these three theoretical observations could collectively serve teachers and students to provide understandings of a rich educational experience that is in keeping with the way that learning has taken place over tens of thousands of years. To help make connections between the different perspectives, the next section shows the theory underpinning MELT, and how this theory enables MELT to connect multiple theories.

4.6 Theoretical Underpinning of MELT

Shrink and its analysis are now taken up to consider the theory that underpins MELT. While Chap. 2 outlined the literature that informed MELT, the MELT comprise a conceptual framework for learning and teaching, not a theory. A conceptual framework, such as Bloom's Taxonomy, provides a structure for thinking, and is not by default theoretical. To a large extent, Bloom's Taxonomy, the ANZIIL framework, and the SOLO taxonomy are themselves descriptive. The MELT function at a level that is explicitly connected to practice. However, there is theory underpinning MELT, and aspects of epistemology and theory provide a fundamental understanding of the ways that MELT may provide a conceptual glue between disparate paradigms, theories and practices.

The MELT were designed to provide bridging points between different educational ideas, by addressing multiple theories, and this is enabled in practical terms through the consideration of *learning autonomy*. The MELT always need to become fluid through the warmth of conversation or the heat of the argument. In a similar spirit, Dewey wrote

> It is the business of an intelligent theory of education to ascertain the causes for the conflicts that exist and then, instead of taking one side or the other, to indicate a plan of operations proceeding from a level deeper and more inclusive than is represented by the practices and ideas of the contending parties [26].

These conflicts, before the Second World War, were over similar issues to the issues that are debated today, including the efficacy of inquiry-based learning versus a focus on content acquisition and mastery [26]. In Dewey's terms, no 'intelligent theory' for education has emerged that has provided a 'plan of operations' that includes different perspectives, although classroom teachers themselves frequently take a practical orientation that is 'inclusive' in Dewey's sense. The MELT provide a plan of operations that is inclusive because it spans the gamut of approaches through its elaboration of *learning autonomy*. This section shows how the MELT proceed from a 'level deeper'.

The MELT are theoretically underpinned by conceptual metaphor [27], which allows for the development of an educational perspective from a deeper and more inclusive level. The idea of conceptual metaphor is that for all but the most concrete representations, human conceptual structures resonate with metaphor. From this perspective, 'objectivism' is based on a thing, the object, [6] being real, tangible, comprehensible, so ‘objective truth’ is where there is a correspondence between the senses and an idea, between what is tangible and what is thought. Objectivism is a complex philosophical position, and within the MELT, it is treated as an extrapolation of a tangible ‘object’ to a conceptual metaphor [27]. This means that objectivism is treated as a metaphorical perspective or ‘reference point’ from which to view learning, not as *the* correct way to perceive learning.

Bestowing metaphor status elevates objectivism above being a theoretical perspective that may be proven wrong to an enduring and valuable way of providing insight into engaged learning and teaching. This status also demotes objectivism from being the theory that influences how learning should happen. The net result of this elevation and demotion is to place objectivism on equal footing with constructivism. This equivalent status enables all three theories under discussion to provide valuable perspective on contemporary learning, in keeping with a *continuum of learning autonomy,* which provides equivalent status to teacher-directed learning and student-initiated learning.

Likewise, constructivism is based on the action ‘construct’—to build, or the noun ‘construct’—what is built. This ‘bricks and mortar’ idea is related to the internal hidden learning processes in which construction happens. With the different emphases of each, personal constructivism focuses on internal sense-making, whereas social constructivism emphasises the role of language and human interaction in mediating what actually gets to that internal world.

From the formulation of the first MELT, objectivism, personal constructivism and social constructivism were held in tension as helpful and mutually reinforcing metaphors that provide insights into learning and teaching [21]. Rather than treating them as theories that compete, they are more like points of reference [21], places from which to stand and capture insights into educative processes.

4.6.1 Theory on Learner and Teacher Autonomy

Clashes between those with differing theoretical referents and metaphors occur when there is a consideration of how much *learning autonomy* should be provided to specific groups of students. No one argues about *whether* students need to be or become autonomous learners, but they do argue about *when* this should happen. Vygotsky’s use of ‘zone’ in the Zone of Proximal Development (ZPD) [17] connotes a metaphorical region in space, an awareness of a breadth of possibilities. He did not articulate a PPD, a ‘Point of Proximal Development’, a place where things are ‘just right’, or a narrow band of performance. In the zone, the part that is closer to the learner is higher in *learning autonomy* as it pertains to the capacity of the learner without support. Further from the learner (towards the outer edge of the zone) is a point beyond her own capacity, but she can successfully demonstrate intended performance at this outer border of competence with support from experienced others. That is, she will demonstrate less *learning autonomy* at this point, and benefit from more guidance, emulating others. With learning that is enabled by such support, a learner increases

Table 4.1 Emphases for objectivism, personal constructivism and social constructivism in terms of the *continuum of learning autonomy*. (The heavier the shading, the more emphasis)

	Prescribed	Bounded	Scaffolded	Open-ended	Unbounded
Objectivism					
Personal constructivism					
Social constructivism					

in her capacity to perform at a more rigorous, sophisticated level. Over time she becomes able to self-direct and self-regulate her learning at this hightened level of competance, *improvising* or even *innovating*, that is with higher *learning autonomy* and with higher competence than before. However, when new concepts are encountered, new skills needed or higher levels of rigour are required, a movement back to the outer edge of the zone, towards lower *learning autonomy*, with guidance from an experienced peer of teacher, is often needed again, with its modelling and structure.

Thus, the ZPD suggests movement from lower to higher *learning autonomy*, from lower levels at the further reaches of the zone to higher levels closer in to the learner's exisitng capacity. Further out, with modelling and guidance, each student learns how to add sophistication and rigour to their learning, and then when the student applies this learning by herself, she works with higher *learning autonomy* in the edge of the zone that is proximal to the student's capacity. For this reason, MELT implies the need for movement from low *learning autonomy* to high, and back [28], like a tidal zone in the complex ecosystem of learning.

From an objectivist perspective, *learning autonomy* should initially be low, providing structured learning environments in which students can acquire a content knowledge base and practice the skills of the discipline. From a social constructivist perspective, autonomy for students should primarily be high, allowing for student ownership and collaborative action. From a personal constructivist position, students are primarily engaging in internal sense-making that emphasises *evaluation*, *reflection*, *analysis* and *synthesis*. These facets span from the highly prescribed to the unbounded, with a concentration of effort that is at the scaffolded level, as shown visually in Table 4.1.

4.6.2 Autonomy and Metaphor Together

From the MELT perspective, objectivism, personal constructivism and social constructivism don't need to be competing theoretical perspectives but can be treated as metaphors that mutually support each other. Each brings to the educational table its own set of strengths. An objectivist perspective will emphasise the development of students' knowledge bases and cognitive skill sets, in keeping with *prescribed* and *bounded learning autonomy*. Objectivists, of course, can and do provide more open-ended tasks, but this is typically once the student is demonstrably ready with the required knowledge and skills.

Those who are more closely aligned with personal constructivism will engineer learning environments that enable students to overcome or skirt misconceptions and to develop robust understanding. There may be some rote learning and more open investigation, but there will be much *scaffolded* learning. Social constructivists will maximise motivation, social interaction and student ownership of learning, treating students more as if they are in a learning partnership with teachers, allowing, as often as possible, for *open-ended* and *unbounded* learning autonomy.

Treating each theoretical perspective as a metaphor that connects to parts of the *continuum of learning autonomy* may facilitate a more complementary approach to education than currently exists, as each perspective then merely emphasises a different place on the continuum. Objectivists know that learning the facts and details of a discipline through discovery modes is inefficient, and that it is easy for students to develop misconceptions, and so become frustrated and anxious. Personal constructivists know that didactic teaching and rote learning do not prompt deep understanding, that misconceptions developed while learning are substantial and long-lived, and that frequently there must be structure to learning. And social constructivists see that unless students own their learning and engage in social processes, their motivation to engage and capacity to learn will be diminished. MELT's *continuum of learning autonomy* calls for each perspective to speak to and complement the others, to provide for each student the full experiences of the entire continuum and a shuttling back and forth across it as they traverse the years of education.

4.7 Trusting the MELT?

One aspect of research that we have found so far is that educational gains made over the timeframe of a semester using MELT can be subsequently lost: skills tend to atrophy unless they are explicitly reinforced after they are learned [29]. Facilitating learning is a long-term business, where students' motivation is crucial to what they attend to long-term. Empirically, MELT requires significant timeframes and repeated exposure. Because engagement is a long-term process, MELT must be tested over educationally significant timeframes—a minimum of a term or semester. Neurologically, long-term memory consolidation is thought to take place over years, not days or even terms [30].

Of the many MELT, only three have undergone some long-term evaluation—the RSD [31–33], OPS [34] and the WSD [35, 36]. Conceptual frameworks cannot be effectively evaluated through any one trial because ways of interpreting and implementing a conceptual framework vary markedly. What is needed are sustained use by practitioners and substantial, diverse and numerous evaluations in many contexts.

Chap. 5 strongly endorses educator action research (AR) as a powerful, context-sensitive means of evaluating MELT, especially if the idiosyncratic aspects inherent in AR can be connected together in a common reporting strategy framed by MELT.

In addition to AR, other research methodologies that probe MELT use are needed:

- Fine-grained participant observation studies.
- Studies of change in student performance over educationally significant time-frames (a minimum of one term, but generally multiple terms or semesters). Generally, multiple measures with qualitative and quantitative data triangulation are needed.
- Longitudinal studies that follow cohorts.
- Randomised controlled trials, if ethics and practicalities allow a true randomisation of student and teacher.

Further ideas and support for research into MELT are available on the website [37, 38]. The simple way to proceed to build the knowledge base for all educators is to start with one cycle of action research, with the intention to use MELT to enhance student sophisticated thinking.

4.8 Conclusion: Conversations and Arguments

Although in education we tend to prioritise our theoretical perspectives, education theory has not overwhelmed practice in the same way that, for example, physics practice is dictated by theory. We do need, however, to keep our educational convictions, because the care and drive to teach is one of the beauties of human existence. But conviction does not have to entail self-aggrandisement, the belief that ‘I am right’ and ‘others with different opinions are wrong’. Nietzsche said, ‘Conviction is a more dangerous enemy of truth than lies’. A rephrasing may capture the heart of this chapter on ‘what do we trust?’—‘Conviction *that I am right* is a more dangerous enemy of truth than lies.’ Is your conviction about the value of a specific way of educating students? Keep your educational convictions, and act on them consistently. But be a little tentative about how right you may be and how wrong others may be in the light of the complexities of human learning. This requires us to consider what we trust and why, and to hold a little more tentatively our own theoretical or practical philosophies.

The MELT foster argument, but not necessarily in order to bring people to a shared viewpoint. That would be an unrealistic goal, given the range of beliefs, values, ontologies and epistemological perspectives that exist even within any one school system. So MELT are not about ‘pulling together’ in the same direction, so much as helping people commit to their best teaching while considering expanding along the *continuum of learning autonomy*, to provide each student with a little more shuttling, and connecting a bit more to others’ teaching. The sheer volume of disparate teaching efforts is a huge untapped resource in education. Disparate efforts can nullify each other, but they can also co-exist and conceptually connect through a consideration of the MELT's *continuum of learner autonomy* elaborating as they do the *facets* of sophisticated thinking.

References

1. Einstein Bubble in Cartoon: Schwarz, D. (1944, March 12). The Einstein theory of living. *The New York Times Magazine*, pp. 16–17.
2. Nuzzo, R. (2014). Scientific method: Statistical errors. *Nature News, 506*(7487), 150.
3. Willison, J. W. (2000). *Classroom factors affecting student scientific literacy: tales and their interpretation using a metaphoric framework* (Doctoral dissertation, Curtin University, Perth, Australia). Retrieved from https://espace.curtin.edu.au/handle/20.500.11937/268.
4. Bloom, B. S. (1956). *Taxonomy of educational objectives. Vol. 1: Cognitive domain*. New York, NY: McKay.
5. Krathwohl, D. R. (2002). A revision of Bloom's taxonomy: An overview. *Theory into Practice, 41*(4), 212–218.
6. Chapline, G. (2003). Quantum phase transitions and the failure of classical general relativity. *International Journal of Modern Physics A, 18*(21), 3587–3590.
7. Thiemann, T. (2007). Loop quantum gravity: an inside view. In I. Stamatescu & E. Seiler (Eds.), *Approaches to fundamental physics* (pp. 185–263). Berlin, Germany: Springer.
8. Jonassen, D. H. (1991). Objectivism versus constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development*, *39*(3), 5–14. Sutton, C. (1993).
9. Sutton, C. (1993). Figuring out a scientific understanding. *Journal of Research in Science Teaching*, *30*(10), 1215–1227.
10. Roth, W. M., & Roychoudhury, A. (1994). Physics students' epistemologies and views about knowing and learning. *Journal of Research in Science Teaching, 31*(1), 5–30.
11. Wodak, D. (2017). Can objectivists account for subjective reasons. *J. Ethics & Soc. Phil., 12,* 259.
12. Moallem, M. (2001). Applying constructivist and objectivist learning theories in the design of a web-based course: Implications for practice. *Educational Technology & Society, 4*(3), 113–125.
13. Davis, N. T., Jo McCarty, B., Shaw, K. L., & Sidani-Tabbaa, A. (1993). Transitions from objectivism to constructivism in science education. *International Journal of Science Education, 15*(6), 627–636.
14. Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*(3), 347–364.
15. Kelly, G. A. (1955). The psychology of personal constructs. Vol. 1. A theory of personality. Vol. 2. Clinical diagnosis and psychotherapy. Oxford, England: W. W. Norton.
16. Wadsworth, B. J. (1996). *Piaget's theory of cognitive and affective development: Foundations of constructivism*. White Plains, NY: Longman Publishers USA.
17. Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.
18. Hayes, C. (2018, March). Podiatric medicine and surgery: Situated learning in simulation with social constructivism. Presented at the Health Education England North East Quality Conference, Durham, UK.
19. Schurz, G. (2015). Ostensive learnability as a test criterion for theory-neutral observation concepts. *Journal for General Philosophy of Science, 46*(1), 139–153.
20. Cowie, B., Jones, A., & Otrel-Cass, K. (2011). Re-engaging students in science: Issues of assessment, funds of knowledge and sites for learning. *International Journal of Science and Mathematics Education, 9*(2), 347–366.

21. Willison, J. W., & Taylor, P. C. (2006). Complementary epistemologies of science teaching. In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphor and analogy in science education* (pp. 25–36). Dordrecht, Netherlands: Springer.
22. Trumper, R. (2001). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education, 23*(11), 1111–1123.
23. Tytler, R. (2002). Teaching for understanding in science: Constructivist/conceptual change teaching approaches. *Australian Science Teachers Journal, 48*(4), 30–35.
24. Vosniadou, S., Ioannides, C., Dimitrakopoulou, A., & Papademetriou, E. (2001). Designing learning environments to promote conceptual change in science. *Learning and Instruction, 11*(4–5), 381–419.
25. Driver, R. (1989). Students' conceptions and the learning of science. *International Journal of Science Education, 11*(5), 481–490.
26. Dewey, J. (1938/1963). *Experience and education*. New York, NY: Collier MacMillan.
27. Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: the Embodied Mind & its Challenge to Western Thought*. New York, NY: Basic Books.
28. Willison, J., Sabir, F., & Thomas, J. (2017). Shifting dimensions of autonomy in students' research and employment. *Higher Education Research & Development, 36*(2), 430–443.
29. Willison, J. (2012). When Academics integrate research skill development in the curriculum. *Higher Education Research and Development, 31*(6), 905–919.
30. Styles, J. (2008). *The fundamentals of brain development: Integrating nature & nurture*. Cambridge, MA: Harvard University Press.
31. Willison, J., & Buisman Pijlman, F. (2016). Ph.D. prepared: Research skill development across the undergraduate years. *International Journal of Researcher Development*, *7*(1), 63–83.
32. Wilmore, M., & Willison, J. (2016). Graduates' attitudes to research skill development in undergraduate media education. *Asia Pacific Media Educator, 26*(1), 1–16.
33. Ain, C. T., Sabir, F., & Willison, J. (2018). Research skills that men and women developed at university and then used in workplaces. *Studies in Higher Education*, 1–13.
34. Missingham, D., Shah, S., Sabir, F., & Willison, J. (2018). Student engineers optimising problem solving and research skills. *Journal of University Teaching and Learning Practice*, *15*(4).
35. Bandaranaike, S. (2018). From Research Skill Development to Work Skill Development. *Journal of University Teaching & Learning Practice, 15*(4), 7.
36. Bandaranaike, S., & Willison, J. W. (2015). Building capacity for work-readiness: Bridging the cognitive and affective domains. *Asia-Pacific Journal of Cooperative Education, 16*(3), 223–233.
37. Research Skill Development for Curriculum Design and Assessment. (2018). Retrieved from www.rsd.edu.au.
38. Models of Engaged Learning and Teaching (2017). Retrieved from www.melt.edu.au.