4. Is scientific understanding an ability?

In the debate on the relation of understanding and explanation that I presented in the previous chapter, an additional concept attracts a lot of attention: abilities (or skills). Peter Lipton refers to abilities in his examples of causation, where subjects are *able* to understand through visual representations or manipulation of systems, and unification, where he refers to Kuhnian exemplars and the scientists' *abilities* to choose and solve new problems that seem similar to the exemplar. According to Jonathan Kvanvig, subjects need to be *able* to grasp relations within or between phenomena. Christoph Baumberger refers to the notion of grasping as well and characterizes grasping as certain *abilities* to perform inferential or counterfactual reasoning, and Steven Grimm specifies grasping as the *ability* to identify the correct relations involved in the object of understanding. Moreover, abilities play a crucial role in the discussion on the nature of understanding. Currently, two options are on the table: either understanding is a type of propositional knowledge, or it is some ability. Among the three accounts of scientific understanding I presented in chapter two, Kareem Khalifa endorses the first option, and Henk de Regt and Finnur Dellsén favor the second. Those who take understanding as being something genuinely different from knowledge carve out this difference in terms of abilities and argue either that understanding is a specific ability, or that understanding at least requires specific abilities that are not necessary for knowledge.

In this chapter, I argue that understanding is an ability. To do so, it is necessary to clarify, first of all, what abilities are and whether they actually are something different from (propositional) knowledge. If it turns out that there is no genuine difference between propositional knowledge and abilities, the discussion whether understanding is an ability or a type of propositional knowledge would be superfluous. Hence, I start with an examination of already existing accounts and analyses of abilities in section 4.1. I address several issues related to the concept of abilities (or knowing-how) and its differences in comparison to (propositional) knowledge (or knowledge-that) in sections 4.1.1 to 4.1.6. On that basis, I develop my own view and definition of abilities in section 4.1.7. I will defend three claims. First, abilities are dispositions to perform some activity successfully with respect to relevant standards. Second, abilities are learned and trained in specific social contexts. Third,

the manifestations of abilities are partially tacit, that the manifestation processes can never be fully accessed by the subject who manifested the ability. In section 4.2, I relate my analysis of abilities from section 4.1 to understanding and argue that understanding is an ability to succeed in making sense of a phenomenon, situation, or experience. Therefore, understanding should not be identified with a type of knowledge. Based on Gilbert Ryle and Micheal Polanyi thoughts on understanding, I maintain that understanding, in contrast to propositional knowledge, is gradual, its manifestations are multi-track as well as context-sensitive, and consistent with my definition of ability. Then, in section 4.3, I claim that the process of grasping relations of phenomena and articulating these relations in form of explanations is the manifestation of understanding phenomena. I will conclude in section 4.4 that understanding, while being an ability and, therefore, exceeding propositional knowledge, still requires some knowledge in order to be manifested. Without having some knowledge relevant for the phenomenon in questions, no subject could make any sense of the phenomenon. Understanding and knowledge enhance in conjunction with each other.

In contrast to the previous chapter on the relation of understanding and explanation, the discussion in this chapter is not limited to scientific understanding. Although I develop an account of *scientific* understanding in this book, it is not problematic to discuss understanding in general at this point. Quite the opposite, any characterization of understanding in general can elucidate the nature of scientific understanding in particular, as there will be some commonalities among different types of understanding. What is unique about scientific understanding will be addressed in chapters five and six. But first, let us clarify what understanding is in general. In order to do that, we first need to get clear what abilities are.

4.1 What are abilities?

The fact that humans possess various skills or abilities to perform outstanding cognitive or physical performances has always fascinated philosophers. Already Plato and Aristotle differentiated and were engaged with the concept of *technê*, usually translated as skills, craft or art, in contrast to *epistêmê*, which is usually translated as knowledge. And still today, knowing-how or abilities are topics of interest in epistemology and metaphysics. Contemporary debates on skills[1] in analytic philosophy

1 In the last decades, ongoing and flourishing debates on abilities and expertise in various fields of philosophy emerged. Since this dissertation is concerned with the concept of scientific understanding, I cannot consider all aspects and arguments that are of concern in the specialized discussions on skills. For a very recent and extensive overview on the debates on skills and expertise, see Fridland, E. & Pavese, C. (eds.) (2021), *The Routldedge Handbook of Philosophy of Skills and Expertise.* Routledge. For an overview on the concepts of abilities, see

are said to have their origins in Gilbert Ryle's approach to this issue and his basic distinction between knowing-how and knowing-that. Let us start from there.

4.1.1 A basic distinction of knowing-how and knowing-that

Ryle's motivation and the main goal of his investigation is to object the then accepted dogma of the 'ghost in the machine'[2], which expects that every valued (i.e. labeled intelligent, clever etc.) practical or material action originates in an internal consideration of regulative propositions. It is only possible to perform an intelligent action if one has thought through the regulative propositions that have an influence on the action. In opposition to this dogma, Ryle argues that intelligent performances are possible without any preceding theorizing and that certain performances, including thinking and theorizing, can in themselves be intelligently exercised. He supports this claim by reference to a vicious regress along two dimensions, which would occur if the differentiation between theorizing and practicing is maintained. First, no intelligent act could ever begin, because considering regulative propositions itself is an act that would have to conform to some regulative proposition that would have to be considered etc. Second, to maintain the strict distinction between theorizing and practical actions creates a gap, which makes it unclear how the intellect might bear on the practice.[3] These two dead-ends of the regress-argument show, according to Ryle, that "to do something [intelligently] (whether internally or externally) is not to do two things, one 'in our heads' and the other perhaps in the outside world; it is to do one thing in a certain manner."[4]

Ryle accuses philosophers of his day of concentrating too much on theories of knowledge that concern the discovery of truths or facts, but which either ignore the methods or ways in which these truths or facts are discovered, or try to reduce the methods to the discovery of facts itself.[5] In contrast, Ryle argues "that knowledge-how cannot be defined in terms of knowledge-that and further, that knowledge-how is a concept logically prior to the concept of knowledge-that."[6] He presents the following example to illustrate his point:

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e.g. Maier, J., "Abilities", *The Stanford Encyclopedia of Philosophy* (Summer 2021 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/sum2021/entries/abilities/ (last accessed April 12th, 2022).

2 See Ryle, G. (1949), *The Concept of Mind*. Chicago, The University of Chicago Press, pp. 26ff.

3 See Ryle, G. (1990 [1946]), "Knowing How and Knowing That." In Collected Papers (Volume 2), Bristol, Thoemmes Antiquarian Books Ltd, pp. 212–225, pp. 212f.

4 Ibid. p. 214.

5 See ibid. p. 215.

6 Ibid. p. 215.

> A pupil fails to follow an argument. He understands the premisses and he understands the conclusion. But he fails to see that the conclusion follows from the premises. The teacher thinks him rather dull but tries to help. So he tells him that there is an ulterior proposition which he has not considered, namely, that *if the premisses are true, the conclusion is true.* The pupil understands this and dutifully recites it alongside the premisses, and still fails to see that the conclusion follows from the premisses even when accompanied by the assertion that these premisses entail the conclusion. So a second hypothetical proposition is added to the store; namely, that the conclusion is true if the premisses are true as well as the first hypothetical proposition that if the premisses are true the conclusion is true. And still the pupil fails to see. And so on forever. He accepts rules in theory but this does not *force* him to apply them in practice. He considers reasons, but he fails to reason. [sic][7]

Even in everyday language, the difference between knowledge-how and knowledge-that becomes apparent, so Ryle argues. When we talk about people's beliefs, opinions, or knowledge-that, we ask for reasons or grounds for accepting a certain proposition, but we never talk about someone believing- or opining-how. In the case of knowledge-how, it is different. We can and do describe *how* certain activities are performed, but we do not ask for the grounds or reasons of someone's performance. When we describe *how* people know to, for example, sing or play tennis, we actually mean that they perform those activities well, i.e. that their performances meet certain standards or criteria.[8]

So, Ryle arrives at a fundamental distinction between two kinds of knowledge. On the one hand, there is propositional knowledge or knowledge-that, which covers knowledge of facts, e.g. that light travels with a speed of $3x10^8$ m/s or that Tokyo currently is the capital of Japan. On the other hand, there is knowledge-how, the knowing how to do something. The concept of knowledge-how includes actions or performances, like reasoning, as in Ryle's examples of the pupil who fails to reason while having all the necessary propositional knowledge, calculating, or physical activities like playing a musical instrument, conducting an experiment, or more basic actions like speaking or walking.

How is Ryle's distinction between knowledge-that and knowledge-how related to abilities or skills? Carlotta Pavese observes that "for many tasks at least, it is intuitive that one cannot be skilled at it without knowing how to perform it."[9] I share this intuition. Since Ryle introduced the distinction of two kinds of knowledge, they have

7 Ibid. p. 216, original emphasis.

8 Throughout this chapter, I use the terms 'standard', 'criterion' and 'rule' interchangeably.

9 Pavese, C., "Knowledge How", *The Stanford Encyclopedia of Philosophy* (Summer 2021 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/sum2021/entries/knowledge-how/ (last accessed April 12th, 2022).

become objects of intensive philosophical discussion and furthermore, "the most recent debate on knowledge-how has intertwined with a debate on the nature of skills."[10] As the (potential) difference in kind between knowledge-how and knowledge-that as well as the relation between knowledge-how and abilities remain contested issues until today, a closer look at these concepts is necessary for clarifying what abilities are. In the next sections, I present further details of Ryle's conception of knowledge-how as well as the work from other scholars who engaged with knowledge-how and knowledge-that. More precisely, and in addition to Ryle's analysis, I will refer to the work from Michael Polanyi and Harry Collins, who made important contributions to the issue of knowing-how, in the next three subsections. Sections 4.1.5 and 4.1.6 will then be devoted to a view from virtue epistemology on abilities, and a critique of that view. I will conclude my occupation with the nature of knowing-how or abilities by providing a definition of abilities in section 4.1.7.

4.1.2 Knowing-how as unconsciously acting in accordance with rules

In order to arrive at a robust justification for a distinction between knowing-how and knowing-that, a more detailed investigation of knowing-how is in need. Ryle identifies knowing how with knowing a rule. And knowing a rule amounts to the ability to perform an action intelligently, not knowing an extra piece of information in a propositional form. The pupil in Ryle's example mentioned in the previous section knows a lot of logic's rules in their explicit form, but he is not able to argue, i.e. acting in accordance with the rules. An intelligent pupil, by contrast, may have no knowledge of formal logic at all, but might still be good in arguing. The basic problem always remains: a fool can have all the knowledge (-that) without knowing how to act upon these rules, whereas a reasonable person might have never learned any explicit rules but manages to perform in accordance with them anyway. Between knowing rules (knowing-that) and applying or acting in accordance with them (knowing-how) lies a fundamental difference. In Ryle's view, in knowing-how to do certain things, the knowledge of a person is actualized or exercised in what he does, without considering any theoretical propositions. And additionally, the performance of a person is somehow governed by specific rules or criteria that apply to performances of a certain sort, e.g. how to make good jokes.[11] For Ryle, the witty person is able to make good jokes and identifies bad ones, but she will not be able to present any maxims or canons that dictate how she is doing this.[12] Importantly,

10 Ibid. For an overview of classical as well as recent arguments in favor of and against a distinction of knowledge-how and knowledge-that, see ibid.

11 See Ryle (1990 [1946]), pp. 217f.

12 See Ryle (1949), p. 30.

"a skill is not an act. […] It is a disposition, or a complex of dispositions."[13] And "phrases such as 'technical skill', 'scrupulous conduct' and even 'practical reason' denote capacities to execute not tandem operations but single operations with special procedures."[14]

Intellectualists object to Ryle's position that knowing-how is independent of and prior to knowing that. They argue that, since knowing-how involves knowledge of a rule in every case, the knowing of this rule amounts to the propositional knowledge of a general hypothetical pattern of the form 'whenever so and so, then such and such'. Ryle has two counterarguments against this suggestion. First, knowing and accepting any set of such hypothetical propositions does not automatically imply that they enable a person to successfully act in accordance with them. One might accept the proposition of how to sew a shirt or ride a bike, but this is not sufficient for performing these activities. On the contrary, a person might know how to ride a bike because she practiced it in a trial and error process without ever knowing explicitly what the rules for successful bike-riding look like. And second, the proposed general hypothetical pattern is an inductive generalization. Generating these generalizations requires valid inductive reasoning, which is in itself an intelligent performance that cannot adhere to the general hypothetical propositions that are a result of this performance. We would end up in an infinite regress again. However, Ryle does acknowledge that it is possible to extract propositional principles from successful activities performed by those who know how to perform these activities, like hunting, tailoring or reasoning. These principles are expressed in the imperative form and not in the indicative, though, which implies that we do accept rules or maxims, but, contra to the intellectualists claim, we do not accept any truths behind them, since truths cannot be expressed in an imperative form, so Ryle argues. Still, the extracted principles serve a crucial pedagogical function: they are guidelines or handbooks for novices who are learning certain activities from those who know how to perform these activities successfully.[15]

Persons who know how to do certain things, how to perform activities or give good advice on these activities, are credited with a certain dispositional excellence. This dispositional excellence is actualized in the performed activities. An excellent cook knows how to create delicious dishes without recalling the recipes, a good chess player does not consciously think of the rules and tactical principles of the game, he simply plays according to them, and the acute reasoner does not consider propositions and glances on formula, he simply takes them into account appropriately in his activity of reasoning.[16]

13 Ibid. p. 33.

14 Ryle (1990 [1946]), p. 214.

15 See ibid. pp. 220f.

16 See ibid. p. 223.

In Michael Polanyi's view, which sounds similar to Ryle's, performing a skillful action requires "the observance of a set of rules which are not known as such to the person following them."[17] This means that an action can be well or skillfully performed without the consideration of explicit rules. In that sense, skills are unspecifiable. Polanyi explicates this idea by referring to the notions of subsidiary awareness and focal awareness, which he takes to be mutually exclusive. When a pianist is playing a concert, his focal awareness is targeted at the piece of music he is playing at that time. While playing a piece of music on the piano, the pianist is constantly moving his fingers, feet, and his whole body to produce the desired sounds, and these bodily movements lie in his subsidiary awareness. If the pianist would try to focus on what he is actually doing with his fingers, feet and body, he would get irritated and stop playing. The human attention can only hold on focus at a time, according to Polanyi. While performing, the focus lies on the piece that is being played, that is, on the activity as a whole. One cannot simultaneously be focally aware of the whole and of its parts. However, the pianist is subsidiary aware of the parts or particulars, the individual notes and his physical activities to produce these notes, while he is playing the piece. The particulars of a certain activity, like producing every single note on the piano, are unconsciously performed or realized. The whole, the meaning or goal that should be achieved by the activity, playing a piece on the piano, lies in the focal awareness. The coordination and correct application of all the particulars is a demanding and complex process that has to be learned.[18]

> We may say, more generally, that by the effort by which I concentrate on my chosen plane of operation I succeed in absorbing all the elements of the situation of which I might otherwise be aware in themselves, so that I become aware of them now in terms of the operational results achieved through their use. […] And again, in practical terms, as we learn to handle [certain tools] in terms of the situation which we are striving to master, we become unconscious of the actions by which we achieve this result. This lapse into unconsciousness is accompanied by a newly acquired consciousness of the experiences in question, on the operational plane. It is misleading, therefore, to describe this as the mere result of repetition; it is a structural change achieved by a repeated mental effort aiming at the instrumentalization of certain things and actions in the service of some purpose.[19]

17 Polanyi, M. (1962 [1958]), *Personal Knowledge. Towards a Post-Critical Philosophy*, London, Routledge, p. 51.

18 See ibid. pp. 57–68.

19 Ibid. p. 64.

Harry Collins provides another, slightly different analysis of 'tacit knowledge', as he calls it.[20] Although Collins uses a different terminology, the notions 'tacit knowledge' and 'knowledge-how' refer to the same kind of knowledge, namely knowledge that is not or cannot be articulated explicitly. He distinguishes three different kinds of knowledge that are often labelled 'tacit': relational, somatic, and collective tacit knowledge. While the first two can be made explicit in principle, the latter remains inherently tacit.[21] The crucial dimension that makes collective tacit knowledge distinct from the other two kinds, and also from explicit knowledge, is the social dimension, according to Collins. He clarifies this idea by discussing the two activities of bicycle riding and bicycle balancing.[22] Bicycle balancing requires the coordination of neural and muscular acts to stay upright on a bike and to move forward. Bicycle balancing is an instance of somatic tacit knowledge, as it can be made explicit through scientific research. The additional component involved in bicycle riding is the social component since activities like bicycle riding take place in a social environment like traffic. In any social setting, not only in traffic, the subject has to make a social judgement about the balancing of the individual and social responsibility in order to keep the setting working.[23] To put it differently, Collins argues that knowledge is ultimately located in society, and individuals merely share the knowledge of the collective in an implicit, tacit way. How humans manage to participate in collective knowledge and connect to society exactly is still obscure. This is the feature that makes collective tacit knowledge inherently tacit.[24] Collins' view in a nutshell, to obtain a certain skill requires the respective collective tacit knowledge. Collective tacit knowledge is a prerequisite for having skills. First a person needs to gain collective tacit knowledge, and then she can train a certain ability that accords with it. Without

20 See Collins, H. (2010), *Tacit and Explicit Knowledge*. Chicago and London, The University of Chicago Press.

21 Relational tacit knowledge can be made explicit in principle and only logistical or social reasons hinder persons to do so. Collins discusses several instances of relational tacit knowledge, e.g. cases of mismatched saliences in which some fact is not made explicit because person A takes for granted that person B knows this fact, while she actually does not. Somatic tacit knowledge is tacit for the individual because of the limits of the human body and brain, but it can be explicated in terms of scientific theories or explanations. Therefore, somatic tacit knowledge, as well as relational tacit knowledge, is not an instance of entirely tacit knowledge because it can be made explicit in principle by scientists. For more details concerning relational and somatic tacit knowledge, see ibid. pp. 85–117.

22 Collins discusses bicycle balancing and chess playing as examples for somatic tacit knowledge. The riders of a bicycle or champions in chess are not able to state explicitly and in every detail how they are riding a bicycle or played a certain chess game at a tournament, although they are able to apply that knowledge in a practical sense. However, science can make this knowledge explicit, see ibid. pp. 99–117.

23 See ibid. pp. 119–123.

24 See ibid. pp. 131–138.

the acquisition of some collective tacit knowledge, subjects could not acquire abilities. Collins' distinction between collective tacit knowledge and abilities resembles Ryle's and Polanyi's analysis, as they also claim that subjects need to possess tacit or implicit rules, that they have the knowledge-how, to manifest skillful performances.

So, according to the three authors, knowing-that is possessing explicit information or facts, while knowing-how is a disposition or capacity to act in accordance with certain tacit rules. Once a subject acquired some tacit rules, she will perform the respective activity well without consciously or explicitly considering any rules. In contrast to knowing-how, knowing-that consist of the possession of explicit facts. If the two types of knowledge differ in the way just described, would the process of learning or acquiring them also vary significantly? Some argue that it does. If this is the case, a differentiation between knowledge-how and knowledge-that as two distinct kinds will become even more plausible.

4.1.3 The acquirement of knowing-how

Unsurprisingly, Ryle is among those scholars who argue that there is a fundamental difference between how we acquire knowledge-how and knowledge-that. According to him, and I am paraphrasing Ryle's way of talking here, the latter involves the instruction of truths and the accumulation of pieces of knowledge-that, of facts. In contrast, knowing-how requires appropriate exercising and being disciplined in methods. The term 'discipline' refers to two different processes, habituation or drill on the one hand, and education or training on the other. Ryle is not concerned with habituation or drill. This measure produces automatisms and blind habits. In drilling novices, they are learning to do something blindly without considering how they are performing their task or why they are performing their task exactly like this or what alternative realizations of the task could be. Contrary to that, Ryle claims that educating or training novices, the second meaning of 'discipline', enables them to develop intelligent powers. In teaching skills, novices learn how to do something intelligently. Training supports and fosters intelligence, whereas drills dispense it. The education of novices allows them to perform exercises in the right way by using their brains, to learn from their mistakes and how to avoid or correct them. Although skills include habits, skills exceed habits in that they allow for the generation of new successful procedures as well as of new propositional knowledge, instead of merely repeating the same activity time and again. Disciplines such as mathematics or philosophy or methods from the sciences could be seen as branches of knowledge-how, not (just) bodies of propositional information.[25] "The experts in them cannot tell us what they know, they can only show what they know by operating with cleverness, skill, elegance or taste. The advance of knowledge does

25 See Ryle (1990 [1946]) pp. 223f.

not consist only in the accumulation of discovered truths, but also and chiefly in the cumulative mastery of methods."[26] Accordingly, "we learn *how* by practice, schooled indeed by criticism and example, but often quite unaided by any lessons in the theory."[27]

Polanyi agrees with Ryle on the nature of knowledge-how and on its acquisition process. For Polanyi, science is a form of art and the art can be passed on only by example from master to novice. This is so because the rules that have to be subconsciously observed to perform skillfully are not explicitly known by any subject, cannot define the respective art in detail, and cannot be conveyed in the form of instructions. Personal contact is required to learn an art. In the case of science, the explicit contents, like theories or explanations, were distributed globally much faster than the art of conducting scientific research.[28] "The large amount of time spent by students of chemistry, biology and medicine in their practical courses shows how greatly these sciences rely on the transmission of skills and connoisseurship from master to apprentice. It offers an impressive demonstration of the extent to which the art of knowing has remained unspecifiable at the very heart of science."[29]

Finally, the necessity of personal contact in the process of acquiring knowledge-how or tacit knowledge, is also stressed by Harry Collins. As it is the social dimension of collective tacit knowledge that makes it inherently tacit, collective tacit knowledge cannot be acquired if one is not situated in a society. How to do things right in a specific social setting cannot be learned by rules, according to Collins, but only by experience. Subjects need to absorb social rules that cannot be made explicit, and they can do so only by being part of a society.[30] Collins provides the example of dance improvisation to illustrate this point. "Improvisation is a skill requiring the kind of tacit knowledge that can *only* be acquired through social embedding in society. Social sensibility is needed to know that one innovative dance step counts as an improvisation while another counts as foolish, dangerous, or ugly, and the difference may be a matter of changing fashion, your dancing partner, and location."[31] Tacit knowledge, knowledge-how, can be acquired through language, through the derived pedagogical principles, but also through physical activity, whereupon Collins takes the participation in physical activity to be the more efficient way for doing so.[32] This is

26 Ibid. p. 223.

27 Ryle (1949), p. 41.

28 See Polanyi (1962 [1958]), pp. 51–56.

29 Ibid. p. 57.

30 See Collins (2010), pp. 119–123.

31 Collins (2010), p. 123, original emphasis.

32 See ibid. pp. 131–138. For more details concerning the advantage of physical activity over mere conversation see, for example, Ribeiro, R. & Collins, H. (2007), "The Bread- Making Machine, Tacit Knowledge, and Two Types of Action." *Organization Studies*, 28 (9), pp. 1417– 1433, DOI: 10.1177/0170840607082228.

consistent with Ryle's claim that propositional knowledge alone is not sufficient for performing any corresponding skillful action and with Polanyi's point that learning skills requires interaction with another, skillful person.

Summing up, how is knowing-how acquired by subjects? How do we learn to do something correctly, or intelligently, or well in any sense? According to Ryle, Polanyi, and Collins, acquiring knowing-how requires learning the tacit social rules and practicing performances that accord with these rules in a social setting. We need to acquire methods and train them by exercising them. Acquiring knowledge-how is a learning by doing procedure that is guided by a master or a social community, who gives the subject feedback on her progress with the method or practice in question. Assessing whether the tacit rules that govern practices have been incorporated by the subject requires other members of the community. Although the novice receives feedback during her training, nobody can tell her explicitly what she needs to do. Ultimately, she has to acquire the knowledge-how herself, through her own experience. This process of acquiring knowledge-how is fundamentally different from acquiring knowledge-that, as in the second case, explicit information or facts are gathered and structured. Knowledge-that requires the possession of explicit information, knowledge-how the awareness of tacit rules. Therefore, not only the nature of the two types of knowledge is fundamentally different, but also their acquisition processes. This is the conclusion at which Ryle, Polanyi and Collins arrive concerning the acquisition process of knowing-how, and I consent to this view.

4.1.4 Manifesting knowing-how is context-sensitive

While having the know-how to perform an activity well requires the possession of tacit rules, it does not amount to simply repeating certain actions in every performance. I already mentioned that Ryle distinguishes between automatism and blind habits on the one hand, and intelligent powers or capacities on the other hand. As an illustration of how intelligent capacities allow a person to modify his performance, Ryle discusses what happens when a person is arguing intelligently. The intelligent reasoner does not simply repeat his argument again and again, as it would be the case if his ability to argue intelligently would merely be a habit, but instead constructs new parts of his argument that did not exist before, i.e. that he did not consider before. This construction of a new argument is due to changing requirements, which occur in every new case of arguing: the meeting of new objections, interpreting new evidence, making connections between elements in the specific situation which did not correspond before. While the intelligent reasoner constructs new arguments and learns with every new case of argumentation, he always reasons logically. The rules of logic are observed in such a way that the intelligent reasoner does not consciously consider them. Instead, the rules of logic became his way of

thinking. The intelligent reasoner reasons in accordance with a specific method, but without reflecting on the prescriptions of the corresponding methodology. The same holds for physical practices, e.g. being a good surgeon. Without any medical knowledge, a person will never become a good surgeon but having a lot of explicit medical knowledge itself is not sufficient for being a good surgeon. A surgeon must have learned the practice of performing surgery, and that might require slightly different decisions on actions and steps during performing surgery on different patients.[33]

Polanyi and Collins can be aligned with Ryle's view on the openness of skills. Polanyi takes the rules of art, which a subjects follows during a performance, as useful and as a guide to an art, while not dictating the practice of the art.[34] Collins' conception of collective tacit knowledge fits well into this picture, too. In order to achieve the respective collective tacit knowledge, a subject needs to have a social sensibility. This, in turn, requires a brain that can assimilate social rules. Since social rules might change with context, the process of learning skills must be flexible. This is different to the training of muscles or habituation, as Ryle calls it. Balancing a bike works the same everywhere, but how to ride a bike in traffic differs with respect to society, that is, to different traffic systems. If a subject wants to learn a skill, she will have to acquire the respective tacit knowledge and to do that, she needs to stay in touch with society. Collins concludes that skill acquisition occurs in two steps or phases. First, the mere acquisition of motor coordination, and second, the acquisition of motor coordination in a socially sensitive way.[35] The collective nature of tacit knowledge and hence of skills is irreducible, because "it is only humans who have the ability to acquire cultural fluency. It is only humans who possess what we can call "socialness" – the ability to absorb ways of going on from the surrounding society without being able to articulate the rules in detail."[36]

Hence, another crucial difference between knowing-how and knowing-that is revealed. I conclude that the manifestation of knowing-how is context-sensitive, it can be changed or adjusted if required. Showing some knowing-how is not mere repetition or habit. Importantly, no matter what exactly a subject changes, the modified performances will still be in accordance with the tacit social rules if performed successfully. Independent of the concrete execution, the skillful performance will always count as a skillful performance. Knowledge-that is not context-sensitive in this way. We take knowledge-that, like the facts that light travels with a speed of $3x10^8$

33 See Ryle (1949), pp. 46–49.

34 See Polanyi (1962 [1958]), pp. 51f.

35 See Collins (2010), pp. 123f.

36 Ibid. p. 125. Importantly, Collins does not claim that animals are not social. All he is saying is that, for example, animals eat their foot in the same manner all around the world, while humans can change their eating manners according to the cultural setting. Even if Collins is wrong in this regard, attributing "socialness" in this sense to humans as well as animals will not affect the ability of humans to modify their performance according to the context.

m/s or that Tokyo currently is the capital of Japan, to be true independent of any context. There is no room for the same kind of variation or interpretation in the case of knowledge-that that as for the manifestation of knowledge-how.

4.1.5 Knowing-how, abilities or skills are stable, robust features

Although the manifestations of abilities are context-sensitive and exceed repetition or habit, as skillful persons can modify their performance if necessary, they also seem to have a stable or robust component. Able dancers, bicycle riders or chess players are called 'able' because they were and are very often successful in their performances. This idea is elaborated by two virtue epistemologists, namely Ernest Sosa and John Greco. Both conceive knowledge as an intellectual success achieved through ability,[37] which again is compatible with the view presented before that knowing how precedes propositional knowledge. Sosa argues that competences, which he identifies with dispositions of an agent to perform well, include three components: its constitution, its condition, and its situation. It is the constitutional competence that Sosa identifies as a skill. A ski jumper, for example, has learned all the skills he needs to be a good ski jumper during his athletic career, he has internalized them. However, to execute a good jump, i.e. to be successful in what he is doing, he needs to be in the right condition, well-trained and prepared for the respective competition, healthy, sober etc. And finally, he needs the favorable situation, good weather conditions, to perform well. The best ski jumper will not be able to execute a good jump in a thunderstorm. The same structure holds for intellectual competences. A theoretical chemist must learn all the skills required for the discipline during her studies. In order to make accurate calculations to predict chemical phenomena, she also needs to be in the right condition (well-rested, focused, sober) and in the right situation. Even for the best theoretical chemist it might be impossible to perform sophisticated computations in an office with 35°C with no air conditioning. The crucial aspect of a skill, the constitutional part of a competence, is, according to Sosa, that the agent always retains the skill, even when she is asleep, ill, or drunk. That is, an agent is always in possession of certain competences even if she is not able to perform these competences well in all conditions or situations.[38] "That you fail a conditionals test when in poor shape or

37 For an overview on virtue epistemology, see for example Turri, J., Alfano, M. & Greco, J., "Virtue Epistemology", *The Stanford Encyclopedia of Philosophy* (Winter 2021 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/win2021/entries/epistemology-virtue/ (last accessed April 12th 2022).

38 See Sosa, E. (2010), "How competence matters in epistemology." *Philosophical Perspectives*, 24, pp. 465–475., DOI: 10.1111/j.1520-8583.2010.00200.x, p. 465.

poorly situated bears not at all on your possession of a corresponding constitutional competence."[39]

John Greco, who studied under Ernest Sosa, also identifies intellectual virtues with abilities or powers of the knowing agent. In his view, knowledge is true belief based on intellectual ability. Starting from this, Greco can explain why knowledge is *creditable* true belief since knowledge is a form of success through ability, and success through ability is worthy of a special sort of credit.[40]

> More generally, the sort of crediting and valuing associated with success through ability (or excellence, or virtue) is ubiquitous in human life. It is instanced in the moral realm, the athletic, the artistic, and many more. […] We credit success through ability more than we credit mere lucky success. But we also *value* success through ability more than we value mere lucky success, i.e., success through virtue or excellence, is identified as the highest human good: it is of intrinsic value itself, and it is constitutive of human flourishing.[41]

If an ability is attributed to an agent, it will mean that she is reliably successful in some way relevant to the respective ability, according to Greco. Moreover, abilities are tethered to significant conditions and the environment. Greco's distinction between condition and environment is not identical to Sosa's differentiation between condition and situation, since Greco takes the concepts of "condition" and "environment" to be overlapping. The only vague distinction that Greco offers is that "environments" refer to sets of relatively stable circumstances, while "conditions" indicate sets of shifting circumstances within an environment.[42] "Finally, to say that someone has an ability to achieve some result is to say both more and less than that they have a good track record with respect to achieving that result. This is because abilities are *dispositional properties*: to say that S has the ability to achieve result R is to say that S has a disposition or tendency to achieve R across relevantly close worlds."[43] That is, abilities as well as their attribution are context-sensitive. Which conditions and environments, that is, which close worlds, are seen as relevant depends on the interests and purposes that are operative in the respective context. If,

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39 Ibid. p. 469.

40 See Greco, J. (2007), "The Nature of Ability and the Purpose of Knowledge." *Philosophical Issues*, 17, pp. 57–69, DOI: 10.1111/j.1533-6077.2007.00122.x, p. 57.

41 Ibid. pp. 57f, original emphasis. Greco develops his account with the goal of explaining why knowledge is incompatible with luck and why knowledge is more valuable than mere true belief. For a more advanced presentation of his account, see Greco, J. (2010), *Achieving Knowledge. A virtue-theoretic account of epistemic normativity*, Cambridge, Cambridge University Press, DOI: 10.1017/CBO9780511844645.

42 See ibid. p. 60.

43 Ibid. pp. 60f, my emphasis.

for example, Oliver states that Thomas has the ability to coach a soccer team well, this statement may have a different meaning, depending on whether Oliver refers to Thomas Tuchel, the coach of the soccer club Paris Saint-Germain, or Thomas, the coach of Oliver's ten years-old son. The ability needed to build a functioning team out of individual soccer geniuses playing on the highest international level is quite different from the ability to coach ten years-old boys in a local league. In these two cases, the relevant conditions and environments are fundamentally different. Greco allows for subject, attributor, or third party contextualism, depending on whose interests and purposes are of concern.[44]

So, once a subject acquired an ability, some knowing-how, this ability will be a constitutional or at least a stable feature of the subject, which means that she has been and will be reliably successful in manifesting this ability in relevant and appropriate contexts. This insight is in line with the result of the previous section: while the ability is a stable, robust feature of a subject, the manifestation of this ability will be sensitive to the given context and, hence, might differ, respectively.

4.1.6 Should knowing-how be tight to success?

Barbara Vetter summarizes Sosa's and Greco's characterization of abilities or competences as "dispositions to succeed".[45] This idea can already be traced back to Ryle, who conceived knowing-how to perform actions as performing these actions well or successfully with respect to certain criteria. Polanyi and Collins approve of this, as I showed. The crucial point about this conceptualization of abilities is that agents will perform a certain action properly if they do it at all. That is, a ski jumper would perform a good jump if he jumps, given an appropriate condition and situation, and Thomas would be a good (able) soccer coach if he were to coach a soccer team.[46] Vetter characterizes Sosa's and Greco's account of abilities as follows:

> *x* has the ability to A iff *x* is disposed to A successfully when A'ing at all, i.e. iff, if *x* were to A at all, then (interferences aside) *x* would (probably) A successfully.[47]

However, Vetter identifies and discusses a crucial problem of this account of abilities. According to Sosa and Greco, the agent's exercise of the ability is tied to success. But what about activities that do not have standards of success, that cannot be performed 'well' in any sense? Aimless ambling and doodling are examples of perfor-

44 See ibid. pp. 60ff.

45 Vetter, B. (2019), "Are abilities dispositions?" *Synthese*, 196, pp. 201–220, DOI: 10.1007/s11229-016-1152-7, p. 214.

46 See ibid. pp. 214f.

47 Ibid. p. 214.

mances which lack any aim as well as any evaluative standard. One cannot amble or doodle in a better or worse way. Either one does amble or doodle, or one does not. It is possible, though, to introduce a trivial success condition: The end of aimless doodling is aimless doodling. If my random doodling ends up in a sketch of my boss, I will have failed to doodle randomly. If my aimless ambling turns into a walk to the train station because I spontaneously want to visit a friend, I will have failed to amble aimlessly. Furthermore, Vetter notes that many verbs, like 'hit', 'move' or 'reach', describe a performance only in so far as it is performed successfully. Therefore, they are called 'success verbs'. Vetter concludes that Sosa's and Greco's characterization of abilities as dispositions to succeed becomes trivial in the cases of success verbs, of aimless activities, and also of simple motor activities (like raising one's arm, moving one's eyes, or wiggle one's foot), because in these cases, A'ing automatically amounts to A'ing successfully.[48]

The consequence of this trivial characterization of dispositions as being disposed to A if A, or that one would A if one were to A, is that either everything has these dispositions, and hence the respective ability (everything can hit a board, amble aimlessly or move something), or that nothing has such dispositions, and the corresponding ability, if there are no such trivial dispositions. Both alternatives are absurd, according to Vetter.[49] Either one would have to accept that, in the case in which a sponge hits the blackboard, the sponge has the disposition to hit the blackboard, and, therefore, the sponge has the ability to hit the blackboard. No one would attribute abilities to sponges, at least not to the ones we find in old-school classrooms to clean the blackboard! Or we would have to deny that dispositions like hitting a blackboard exist. If we do that and if, at the same time, we side with Sosa'a and Greco's characterization of abilities as dispositions to succeed when you try, we could rule out absurd attributions, but we would have to deny that anything or anyone has the disposition, and therefore the ability, to hit the blackboard. Ergo, no one would be able to hit a blackboard, which is definitely not true, as some students might frequently hit the blackboard when throwing a sponge at it, while others might often fail to hit the blackboard with the sponge. Given these problems with 'abilities as dispositions to succeed', Vetter concludes that this "account failed to ensure that the manifestation for the correlated disposition is always sufficiently distinct from the performance itself and thereby fails to capture at least a great deal of our simple motor abilities."[50]

48 See ibid. pp. 215f.

49 See ibid. p. 215.

50 Ibid. p. 217. In general, the notion of manifestation refers to the process or event of becoming visible or the revelation of all kinds of things, which were invisible or shapeless or even non-existent before the manifestation took place. For an overview of topics concerning dispositions and manifestations that are addressed in philosophy, see for example Choi, S. & Fara, M., "Dispositions", *The Stanford Encyclopedia of Philosophy* (Spring 2021 Edition), Edward

Generally, Vetter is interested in the nature of abilities and starts her own investigations with the insight that abilities are commonly referred to as dispositional properties, an idea that can also already be found in Ryle's work. However, not every disposition would ordinarily be considered an ability, like the dispositions to get provoked or get a sunburn easily. And the question which dispositions are abilities is still not answered conclusively. This is the context in which Vetter discusses the views of virtue reliabilists like Sosa and Greco. She wants to show that this view fails to fully capture the intuitive notion of ability, but she does not provide an alternative answer to the question which dispositions are abilities. It might even be possible that there is no unified, reasonable conception of ability that captures all sorts of abilities. Rather, it could be that the term 'ability' covers are large number of (partially) overlapping meanings. However, if this is the case, these meanings need to be worked out in detail, which has not been done yet. To conclude, on the one hand, it is still not clear what it means to have an ability. Yet, it is obvious that agents have abilities. Agents are able to vote, drive a car, and do all kinds of things.[51] As Vetter puts it, "our abilities – unlike the opportunities with which the world presents us – tend to be stable, robust features of ourselves that we can rely on in a large variety of different situations. The ability […] is there to be called upon, even when it is presently lying dormant, that is, unexercised."[52]

4.1.7 Abilities are dispositions to succeed

Where does this discussion of abilities leave us, what are abilities? I am now in a position to present my own view on that matter. Although Vetter's critique is a challenge to any general account that characterizes abilities as dispositions to succeed, it is not a problem for activities that do have standards of success and which do serve an aim. Since she does not propose any alternative conception of ability and does allow for the possibility of several and potentially overlapping conceptions of abilities, I do not see a problem in sticking with the idea that some abilities are disposition to succeed, or to perform well or in accordance with some given standards. Again,

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N. Zalta (ed.), URL = https://plato.stanford.edu/archives/spr2021/entries/dispositions/ (last accessed April 12th, 2022).

51 See Vetter (2019), pp. 201f, 218f. In addition to the view of virtue reliabilism on abilities, Vetter also discusses an alternative approach. Namely, the project called 'new dispositionalism' from the debate on free will, which states that abilities are dispositions to do what one intends to do. Discussing the arguments from the new dispositionalism here would lead to far and Vetter identifies severe problems with this view of abilities, which I take to be more serious than her criticism of virtue reliabilism. In short, new dispositionalism cannot account for abilities that are incompatible with trying, like creative or sub-intentional actions. For more details, see ibid. pp. 205–214.

52 Ibid. p. 202.

as Vetter notes, this characterization does not accommodate all abilities that agents possess, but it does accommodate those kinds of abilities I am interested in in the context of scientific research. I agree with Vetter that the questions what abilities are and whether one unified conception of ability is possible are interesting and important. However, they lie outside of the scope of this book.

Let me quickly turn to the inconsistent terminology used by the various authors I refer to. Throughout this section, terms like knowing-how, skill, ability, or competence appear. Ultimately, I think that the terminological variation does not point to a fundamental metaphysical difference. The authors I address in this section employ expressions like 'someone has the ability to x, has the skill to x, has the know-how to x, or has the competence to x' to refer to the same thing. They all denote that someone can do something in an appreciated or valued manner. The only concept that slightly steps out of line is 'disposition', since we would not call every disposition an ability. Just because a sugar cube has the disposition to dissolve in water, no one would say that sugar cubes are able to dissolve in water. Hence, not all dispositions are abilities. But if we focus on those dispositions that have standards of success, we can say that the terms 'ability', 'skill', 'know-how', and 'competence' can all be defined as denoting someone to have a disposition to perform some activity successfully with respect to relevant standards.[53]

Fortunately for my purpose, science is a context that has established standards of success, albeit different ones in different disciplines, which have to be met when performing certain activities in the course of scientific research. A study or experiment can be set up and conducted well or badly, a specimen can be prepared well or badly, a laser system can be adjusted well or badly, a questionnaire can be devised well or badly. The kinds of abilities that are not captured by the 'abilities as dispositions to succeed'-view, performances described by success verbs, aimless activities, and simple motor activities, are not the kinds of abilities that play an important or central role in scientific research. All abilities or skills that scientists learn over the course of their training are highly specialized abilities, which ultimately serve the aims of conducting good science, discovering truths about the world, understanding and explaining natural and social phenomena, making correct predictions, improving people's lives and possibly even more or different aims. If the highly specialized skills that scientists acquire would not serve some purpose, scientists *qua* scientists would not learn and train them in the first place. Hence, the 'abilities as dispositions to succeed'-view suits the characterization of the very specific and purposeful skills learned and exercised by scientists. Moreover, the 'abilities as dispositions to succeed'-view also accommodates many activities outside of the scientific realm.

53 If it turns out that I wrongly equate these terms, I will happily only use 'ability' and 'disposition (to succeed)' and refrain from using 'skill' and 'competence'. However, I am not aware of a good reason or argument to do so.

Throughout this section, I mention examples from various domains, including being an able, and hence reliably successful, cook, chess player, bicycle rider, surgeon, reasoner, or athlete. As these performances are not characteristic for science, except for reasoning, they will have to meet standards of success different from those found in science. That different performances must meet very different standards of success in different domains or realms, however, is not a problem for the 'abilities as dispositions to succeed'-view, as this view does not prescribe any specific standards that must be met. It only implies that some standards of the specific context in question have to be met. Therefore, while science certainly is one prominent example of a domain with established standards for determining successful performances, it definitely is not the only one.

So, the abilities that scientists acquire in their training are dispositions to succeed in what scientists do when exercising those abilities. Furthermore, as Sosa and Vetter emphasize, abilities are stable, robust, and constitutional features that, once acquired, are permanently possessed by the subject even when they are not manifested. In order to acquire an ability, that ability must be learned and trained. And to learn an ability is to learn the respective tacit, non-propositional rules that guide certain actions. As Ryle, Polanyi and Collins argue, the relevant rules can only be learned by participating and practicing in a social setting and not from a rulebook, due to their tacit nature. For science, this amounts to young researchers learning from the example and criticism of their supervisors and more experienced colleagues by actively participating in the scientific community. Although there is no guaranty that scientists with certain abilities will always be successful, since certain conditions or situations might prevent them from succeeding, they will be successful in the appropriate or sufficiently standardized context. Yet, according to Ryle, it is an important feature of skillful performances, of the manifestation of abilities, that they can be changed or adjusted in cases where the context requires changes or adjustments, while continuing to act in accordance with the tacit rules that prescribe how performances in scientific research are to be done. And recall, possessing an ability means to act in accordance with the rules without actively reflecting on these rules. Ryle calls this the internalization of the rules, and Polanyi accommodates this aspect with his discussion of subsidiary and focal awareness. When a scientist is conducting an experiment or performing a calculation, her focal awareness is on the experiment or on the calculation. Without being consciously aware of it, the able scientist performs skillful research in accordance with the scientific rules of her discipline.[54]

54 The tacit nature of abilities might actually be a problem for the new dispositionalism, the second view that Vetter discusses in addition to virtue reliabilism and which I do not address. But I want to mention here that if, according to the new dispositionalism, an ability is a disposition to do X if one intends (or tries, or chooses, or decides) to do X, then the exercise of an ability must always be preceded by an intention, attempt, choice, or decision. Vetter, who

Based on the discussion of abilities in this section, I propose and use the following definition of ability:

> *x* is an ability if and only if *x*
>
> i. is a disposition to perform a cognitive or physical activity successfully with respect to relevant standards,
> ii. has been learned and trained in a specific social context, and
> iii. manifests in processes that are partially tacit (i.e. that can never be made fully explicit).

In saying that the manifestations of the abilities are partially tacit, I mean that no subject will be able to figure out and describe precisely how she managed to manifest an ability. This claim is not only in line with Ryle's idea that the rules of a specific performance become the way of acting of the skillful person without any conscious reflection, but also with Polanyi's differentiation between subsidiary and focal awareness and with Collins' notion of collective tacit knowledge. Consider the two examples of dance improvisation and logical reasoning. The former is an instance of the manifestation of a physical ability, the latter of a cognitive ability, an ability that takes place purely in the mind of a subject. In both cases, no subject will be able to accurately describe in all detail which muscles or which neurons did what at which point in time during the performance. No one will be able to describe in detail how he managed to come up with some form of improvisation that he never knew of before, or how she was able to construct a syllogism in her mind that she never considered before. While we are focused on demonstrating a mesmerizing innovative dance performance or on constructing a valid and sound argument, we are focused on performing. But we are not and *cannot* be aware of how we manage to coordinate all the activities of our body and mind, which are necessary to perform well, in accordance with the social rules at play. Note, it is not tacit for us whether we did carry out a specific performance in the end, whether our performance was skillful

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does not directly refer to a tacit nature of abilities, provides convincing examples that, first, agents can exercise plenty of abilities without trying, intending, choosing or deciding to do so in advance. And second, that some abilities are only exercised when the agent does not try, choose, decide, or attempt to exercise them, like creative abilities. An agent might have the intention to present a dance performance fantastically, to play the piano with virtuosity, or to conduct an experiment accurately, but while she is focusing on this 'bigger' performance, she cannot pay attention and cannot intend to perform any tiny movement, adjustment, or reasoning step that is involved in presenting a dance performance, playing the piano with virtuosity, or conducting an experiment accurately.

or not. Imagine a cheering crowd around the dance floor and the judges award you a high score for your performance, or you presented a logical argument that your supervisors and peers accepted as a correct and maybe even a good argument. Then we can be pretty confident that we performed the activity in question successfully with respect to the relevant standards that we learned by being in the respective social context that is decisive for the performance in question. As these social standards or rules are implicit themselves, we can neither explicate the rules themselves, nor how we managed to act or perform in accordance with them.

Importantly, I am not claiming that abilities are always independent from knowledge-that or that the two are mutually exclusive! In order to acquire or manifest some ability, subjects may actually need some propositional knowledge. Propositional or explicit knowledge may be necessary for some abilities. For example, a first semester student in philosophy may first have to gain explicit knowledge about what a syllogism is and how to construct one, before she can start to practice and train constructing syllogisms herself. However, I argue that having some propositional knowledge is neither sufficient for also having some ability, nor for manifesting that ability. The philosophy student might have the (propositional) knowledge what a syllogism is and how it is constructed, but when asked to demonstrate this and construct a syllogism herself, she may be unable to do it. In case she acquired the ability to construct syllogisms, she will be able to do this, to manifest the ability, without consciously reflecting on the propositional knowledge of how this is to be done. She will simply do it without explicitly considering how she is doing it. This is the sense in which I take knowledge-that and knowledge-how to be distinct kinds.

After arguing that knowing-how is fundamentally different from propositional knowledge and having arrived at a definition of abilities, I am now in a position to address the central question of this chapter. Is understanding an ability, a kind of knowing-how, or is it more plausible to conceptualize understanding as a type of propositional knowledge?

4.2 Understanding, an ability in itself

In chapter two I indicated that there are two opposing camps concerning the nature of understanding. One camp, including Kareem Khalifa and Peter Lipton, takes understanding to be a kind of (propositional) knowledge, the other, with such members as Henk de Regt, Jonathan Kvanvig or Christoph Baumberger, views understanding as a specific ability. In this section I will side with the latter and argue that understanding should be conceptualized as an ability: It is the ability to make sense of experiences, situations, or phenomena in the world. Importantly, the analysis in this section concerns understanding in general and is not limited to scientific under-

standing. However, if I succeed in showing that understanding is reasonably captured by my definition of ability, specific types of understanding, including scientific understanding, will likely be accommodated by my definition as well. To get started, let us take another look at the authors I was concerned with in the previous section.

4.2.1 Early views on understanding as an ability

Already Gilbert Ryle was concerned with the notion of understanding in his investigation on knowledge-how and asked: "What is this difference between merely witnessing a performance and understanding what is witnessed? What, to take another example, is the difference between hearing what a speaker says and making sense of what he is heard to say?"[55] According to Ryle, "understanding is a part of knowing *how*. The knowledge that is required for understanding intelligent performances of a specific kind is some degree of competence in performances of that kind."[56] It has to be noted that Ryle does not talk about understanding natural or social phenomena, but rather actions performed by other individuals. Consider the following baseball example as an illustration. A spectator who knows nothing about baseball and its rules and has no minimal competence to play baseball will not understand whether the players he observes on the field are playing intelligently or not. He would not be in a position to judge the actions of the teams playing.

According to Ryle, the abilities of appreciating certain performances and executing these performances, like understanding something, are a specific capacity, namely multi-track, and not single-track, dispositions. Recall that these allow for a wide variety of more or less similar practices. Single-track dispositions cover reflexes or habits, meaning that single-track dispositions amount to the same behavior every time it is manifested. Multi-track dispositions, in contrast, refer to capacities of adhering to certain criteria without imposing any or a specific performance that meets the criteria. To this, Ryle adds two important provisos. Namely, that the capacity to execute and appreciate performances does not necessarily involve the ability to articulate criticism about them, and that the ability to perform a specific operation is more demanding than the ability to appreciate it. If this would not be true, there would be no teachers and students who admire their teachers' performances.[57] That is, usually agents first learn how to distinguish excellent from clumsy performances, which requires already some degree of understanding the performance, before learning how to perform excellently themselves.

55 Ryle (1949), p. 51.

56 Ibid. p. 53.

57 See ibid. pp. 46, 54f.

Ryle also relates the concepts of understanding, partial understanding and misunderstanding to his notion of knowledge-how. He wants to strengthen his view that understanding is a part of knowing-how even more by comparing the partial nature of knowledge-how and understanding in contrast to (propositional) knowledge. For both understanding and knowing-how it is natural to speak about someone understanding, e.g. chess partially or having partial knowledge of how to play chess. In contrast, it is not possible to speak about the partial knowledge of individual truths or propositions in the same way. Although it is possible and appropriate to talk about partial knowledge about a topic that involves many propositions, it is not possible to say that 'I partially know that today is Monday'. Whereas knowledge can only be imparted, ways of doing can only be inculcated, and inculcation is a gradual process. The gradual nature of knowing-how and of understanding is the source of misunderstanding. Only if someone partially understands Japanese could he misunderstand a text written in Japanese. Therefore, Ryle arrives at the both comforting and motivating conclusion that mistakes are exercises of competence. Without having partial competence, it would not be possible to make mistakes. And importantly, where there are mistakes or misunderstanding, there always is the possibility to correct these mistakes and to gain (a better) understanding. Therefore, learning and participating in controversies is crucial for gaining knowledge-how and understanding as a part of knowing how.[58]

Not only Ryle, but Polanyi, too, is concerned with ideas about understanding, misunderstanding, and sense-making, which he discusses in the context of articulation. Let's have a closer look at Polanyi´s investigation of, as he calls them, articulate and inarticulate intelligence, and how they relate to understanding.

Polanyi starts his analysis with a presentation of three classes of inarticulate intelligence that animals and young children possess as well. These are contriving a skillful action (like a rat learning to depress a lever to receive food), observing a sign-event relation (like a dog learning that the sound of a bell is followed by the appearance of food), and understanding a situation (like a rat that, after learning to run a maze without obstacles, will find the shortest alternative way when some path is blocked). Acquisitions of these types of intelligence are instances of latent learning in which an animal reorganizes its behavior. It exploits a specific means-ends relation to serve some purpose. Understanding a situation is the most elaborate class of inarticulate intelligence because it can be manifested in more numerous and less predictable ways than contriving or observing a situation. The achievement of understanding, the ability to derive various alternative modes of behavior based on the acquired latent knowledge of the situation, represents a basic logical operation that foreshadows the usage of an articulate interpretative framework. In its function as a representation of a complex situation, an articulate interpretative framework

58 See ibid. pp. 57–59.

allows for ever new inferences concerning possible future aspects of the situation with only a minimal exploration of it. Polanyi claims that these three classes of animal learning are three primitive faculties that are more highly developed in humans, meaning that understanding amounts to an act of interpretation when articulation is involved.[59]

When talking about language, Polanyi includes not only writing, but also other forms of symbolic representation in the notion of language, like mathematics, graphs, maps, diagrams, or pictures. This broad notion of language is due to the two principles of language that Polanyi identifies. One principle covers the process of linguistic representation, the other controls the operation of symbols for contributing to the process of thought.[60] Polanyi summarizes the first principle as the application of "the theory of the universe implied by our language to the particulars of which we speak."[61] In his view, this is what humans do when they learn a language, its vocabulary and grammar, and use it to talk about things. Polanyi takes this process to be necessarily unformalized and inarticulate. Learning and applying language to things, denoting things, is a skill in itself. For example, I get to know the English word 'tree' and learn that the word denotes certain objects that have specific features. Once I learned the word 'tree' and the related concept, I will be able to apply it to new objects that fall under the concept, I will be able to call new objects 'tree'. The second principle that Polanyi introduces covers cases of using language for thought. This is an even more demanding ability since it requires the reproduction, storage, transport and re-arrangement of language symbols. A representation of experience needs not only to denote a thing (first principle of language), but rather has to be devised or applied in order to reveal some new aspect of it (second principle of language). For example, if I face an object that I cannot immediately identify as a tree or a bush, I will reorganize the linguistic symbols I possess in order to make sense of that object. Is it a tree, a bush, something else? Polanyi calls the ability to represent experiences in terms of manageable symbols that can be reorganized in order to yield new information the ability of interpretation. However, Polanyi does emphasize that new information is not supplied by merely manipulating symbols. To count as an instance of a real enhancement of intellectual powers by adequate symbols, to gain genuine understanding of an experience or situation, the manipulation of symbols needs to be accompanied by an inarticulate skill of reading the results of the manipulation.[62]

59 See Polanyi (1962 [1958]), pp. 72ff, 76–79.

60 See ibid. pp. 81–84.

61 Ibid. p. 84.

62 See ibid. pp. 84ff.

> [This] performance does require a measure of controlling intelligence. The original situation […] must be understood and the problem involved in it clearly recognized; then its symbolic representation, including the subsequent operations, has to be correctly performed and the result correctly interpreted. All of this requires intelligence, and it is in the course of these tacit feats of intelligence that the formal operations utilized in the process are accredited and their result accepted by the person carrying them out.[63]

Polanyi specifies how the tacit or personal dimension contributes to the explicit or formal dimension, how language and thought are related, by looking at cases where the two domains fall apart.

> More precisely speaking, we should say that we are referring […] to a state of mental uneasiness due to the feeling that our tacit thoughts do not agree with our symbolic operations, so that we have to decide on which of the two we should rely and which we should correct in the light of the other. […] There will always remain certain chances of error – and even of grave error – which arise from our very adoption of an articulate interpretative framework.[64]

That is, the theory of the universe that is implied by any language might be wrong, either completely or with respect to certain aspects of the world. To determine whether a language captures truths about the world, the text (the part of language in question), the conception suggested by it, and the experience on which it might bear have to be considered. Then, three options remain: the language, and thereby the text, is modified, the experience is reinterpreted, or the text is dismissed as meaningless altogether.[65]

Beneath this intellectual strive to establish coherence among language and perception acts an active principle that humans and other animals possess, so Polanyi argues. This principle urges them to discover truths in the world through perception and, in the case of humans, also through language. "We strive for understanding and satisfy our desire for it by seeking to frame conceptions of the greatest possible clarity."[66] Since this striving is already manifested in perception, e.g. when the lens of one's eye gets adjusted by muscles in order to see a certain object sharply, it highlights the important contribution of sense perception to the tacit components of articulated knowledge.[67] "If perception prefigures all our knowing of things, drive satisfaction prefigures all practical skills, and the two are always interwoven. […]

63 Ibid. p. 87.
64 Ibid. pp. 97f.
65 See ibid. pp. 98f.
66 Ibid. p. 100.
67 See ibid. pp. 100–103.

Therefore, at each of the innumerable points at which our articulation is rooted in our sub-intellectual strivings, or in any inarticulate feats of our intelligence, we rely on tacit performances of our own, the rightness of which we implicitly confirm."[68]

These considerations on an active principle or strive to make sense of the world that, in Polanyi's words, urges all increase in knowledge through perception or language sheds some light on the tacit faculty that enables humans to conciliate experience and language.

> [Humans possess a] power for comprehending a text and the things to which the text refers, within a conception which is the meaning of the text. […] The urge to understand experience, together with the language referring to experience, is clearly an extension of this primordial striving for intellectual control. The shaping of our conceptions is impelled to move from obscurity to clarity and from incoherence to comprehension, by an intellectual discomfort similar to that by which our eyes are impelled to make clear and coherent the things we see. In both cases, we pick out clues which seem to suggest a context in which they make sense as its subsidiary particulars.[69]

Polanyi repeatedly emphasizes the inextricable relation between articulate and inarticulate intelligence.

> This is the sense in which I called denotation an art. To learn a language or to modify its meaning is a tacit, irreversible, heuristic feat; it is a transformation of our intellectual life, originating in our own desire for greater clarity and coherence, and yet sustained by the hope of coming by it into closer touch with reality. Indeed, any modification of an anticipatory framework, whether conceptual, perceptual or appetitive, is an irreversible heuristic act, which transforms our ways of thinking, seeing and appreciating in the hope of attuning our understanding, perception or sensuality more closely to what is true and right.[70]

Like Ryle, also Polanyi draws a connection to misunderstanding in the context of re-interpreting language. Since our articulate interpretative frameworks will never be immune to inappropriateness and therefore to revision, our understanding of language as well as of the aspects of the world that are denoted will change when language is re-interpreted. When committing verbal mistakes that originate from some inappropriate conception of certain aspects of the world, the subject will feel puzzled and might recognize or even overcome her misunderstanding. Polanyi

68 Ibid. pp. 104f.
69 Ibid. pp. 105f.
70 Ibid. p. 111.

presents an example from chemistry in which re-interpretations allowed for a better understanding. When John Dalton introduced the atomic theory of chemistry in 1808, it was immediately accepted. The atomic theory basically states that all matter is composed of atoms, that all atoms of one element are identical, and that atoms of different elements differ in size and weight. Although chemists used the atomic theory universally, it was not very well understood. Only fifty years later, in 1858, Stanislao Cannizzaro introduced a new articulate interpretative framework in form of a distinction between atomic weight, molecular weight and equivalent weight (weight per valence). These related conceptions have been used interchangeably before, which led to some confusion and conflicts in the chemical community. For example, Dalton rejected Avogadro's Law because it contradicted the atomic theory.[71] As Polanyi states, "the appositeness of Cannizzaro's interpretative framework brought new clarity and coherence into our understanding of chemistry."[72]

Cannizzaro improved the language of chemistry due to his better understanding of the subject matter, which allowed him to develop and use a more appropriate interpretative framework. Polanyi describes the form of confusion, which arose for example in the chemical community in the early 19th century, as a deficiency of intellectual control. Such a deficiency of intellectual control amounts to discomfort and can only be remedied by conceptual and linguistic reform. The divergence of text and meaning, of language and experience, in science but also in everyday life, indicates a problematic state of mind. Every time this is resolved, that is, when the text or experience is re-interpreted or when a text is dismissed as meaningless, some new meaning is created that adheres to standards of clarity and reason. That is, we call a newly discovered kind of beetle a beetle and not a butterfly, because our conception of beetle by which we include the new species makes sense. A modification of our conception of butterfly to cover the new species would not make sense.[73]

Polanyi then relates his discussion of the inarticulate and the articulate manifestations of intelligence to his notions of subsidiary and focal awareness already mentioned throughout section 4.1. While humans pay attention to a specific situation they are concerned with, they subsidiarily adjust conceptions they already possess and change the use of their language so that they can accommodate new things that

71 See ibid. pp. 112f. Atomic weight, nowadays called atomic mass, is the mass of atoms of chemical elements. Molecular weight, also known as molecular mass, is the sum of the atomic masses of all the atoms in a molecule. Equivalent mass or, in former times equivalent weight, for chemical elements is the atomic mass divided by the valence. It is the mass of an element which is able to bind or displace one gram of hydrogen. For example, the equivalent mass of oxygen is 16/2 = 8. The valence depends not only on the element, but also on the chemical reaction under consideration.

72 Ibid. p. 113.

73 See ibid. pp. 113–117.

were recognized as new versions of already known kinds of things. The focal attention is targeted at making sense of the situation we are facing, as our inarticulate intelligence adapts and modifies our conceptual framework. This process is comparable to the unconscious interpretation of sensory cues in the context of perception or to the extension of skills by practicing them in as yet unknown situations without being focally aware that one is extending one's skill, so Polanyi argues.[74] The subsidiary search for words to manage a new situation keeps changing the meaning of language. This ability is ultimately manifested in the existence of many different languages, which emerged because different groups of people in different regions of the world at different points in time arrived at different conclusions concerning the conceptions and words they use. The alternative conceptual frameworks sustained by different groups are of course influenced by the things that these groups experience. As a result, the conceptual frameworks express specific theories of the world. Every child accepts the respective theory of the universe implied in a language in the process of learning that language, and every intellectual strive of adults will happen within this framework. One important implication of this according to Polanyi is that humans are divided into groups due to their different vocabularies to interpret the world. This leads to groups that cannot understand each other's way of seeing the world.[75]

In sum, Polanyi argues that any kind of human thinking or reasoning about the world is not possible without language and that we cannot understand any situation or phenomenon in the world without employing our respective language. In his own words:

> Speaking more generally: in order to analyze the use of a descriptive term we must use it for the purpose of contemplating its subject matter, and an analysis of this contemplation will inevitably extend to the contemplated object. It will thus amount to an analysis of the conception by which we are jointly aware both of the term and the subject matter, or more precisely, to an analysis of the particulars covered by this conception: from which we may derive both a more rational use of the term and a better understanding of the things which it designates.[76]

4.2.2 Understanding is gradual, multi-track, and its manifestations context-sensitive

What can we take from Ryle and especially Polanyi for a concept of understanding? First, both explicitly state that they take understanding to be a competence, a dis-

74 See ibid., p. 118

75 See ibid. p. 118.

76 Ibid. p. 122.

position, or a form of inarticulate intelligence, because understanding comes in degrees. It is natural to speak of understanding something only partially, as it is natural to speak of any competence to be only partially acquired by a subject. This is not the case for (propositional) knowledge. One knows *that p*, or one does not know *that p*, but one does not partially know *that p*. Second, both Ryle and Polanyi expect that understanding can be manifested in various possible and unprecedented ways. To be a multi-track disposition, Ryle demands understanding to meet certain criteria without following any specified procedure. Polanyi takes understanding to be the most elaborated class of inarticulate intelligence, as it enables the generation of alternative and non-predicted results. So, it is not only the case that understanding comes in degrees, that is, that certain experts have a better understanding of their field of expertise in comparison to laypeople, but also that the experts among themselves might have a different understanding of the very same phenomena they are concerned with, since they could understand one and the same phenomenon quite differently from each other. Third, and this point has been stressed by Polanyi specifically, a crucial factor for human understanding is language, an articulate conceptual framework. The languages humans learn and adopt through growing up in specific cultures are the reference frames in respect to which humans understand the world and phenomena in it. Different scientific disciplines or communities, which can be viewed as cultures[77] themselves, developed sophisticated and formalized languages that can accommodate the phenomena these disciplines are concerned with. As different cultures developed different formalizations of the world, different concepts and different languages, they understand the world differently and might not be able to make sense of the conception that another person using a different language applies to certain phenomena.[78] Hence, while experts might understand the same phenomenon differently by using different articulate conceptual frameworks, they will all have manifested the same ability, namely understanding, through aligning language and the phenomenon.

These three aspects, the partial possession or mastering of a competence, the multi-trackness that gives room for various forms of manifestation of the understanding, and the dependence on specific articulated conceptual frameworks, allow for making mistakes or for misunderstanding something. Something like this

77 As for example Knorr-Cetina argued, see Knorr-Cetina, K. (1999), *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge (MA), Harvard University Press, DOI: 10.4159/9780674039681.

78 Thomas Kuhn and Paul Feyerabend had similar thoughts and introduced the idea of incommensurability (of scientific theories) in the 1960s. For an overview see Oberheim, E. & Hoyningen-Huene, P., "The Incommensurability of Scientific Theories", *The Stanford Encyclopedia of Philosophy* (Fall 2018 Edition), Edward N. Zalta (ed.), URL = https://plato.stanford.edu/archives/fall2018/entries/incommensurability/ (last accessed April 16th, 2022). I thank David Lambert for pointing this out to me.

is not possible in the case of knowledge. There is no meaningful way of saying 'I have misknown *that p*', although it is perfectly appropriate to say that I misunderstood *p*. Let me elaborate these three features with some examples.

The first aspect of understanding on which Ryle and Polanyi agree is its gradual nature. In the current debate on understanding among epistemologists and philosophers of science, the gradual nature of understanding is one of the few aspects that is not being challenged by anyone as far as I know. It is not clear, however, how exactly differences in the degree of understanding shall or could be accommodated.[79] Despite the varying attempts to spell out differences in degree of understanding, nobody would oppose that, say, a first grader's understanding of volcanic eruptions is not as good as the understanding a first semester geology student has of volcanic eruptions, which again is probably not as good as the understanding that a geology professor has of volcanic eruptions. I will come back to the graduality of understanding in chapter six in the context of my account of scientific understanding.

The second aspect concerns the feature of understanding being a multi-track disposition. Understanding can be manifested in various unprecedented ways by still adhering to given standards. This idea can be clarified by referring to the second principle of language that Polanyi introduces. To understand a new experience, situation, or phenomenon, an agent needs the ability to manipulate symbols correctly and interpret the result of the manipulation correctly. To correctly manipulate and re-interpret symbols amounts to adhering to the rules of grammar of the respective language and to accommodating the experience. Bringing experience and language into line is an ability. While we are consciously trying to make sense of an experience, we have no access to the ways in which our mind tries to conciliate language and experience. Recall the three options that Polanyi offers for these cases. One could dismiss a text, that part of the language that is targeted towards a specific experience, altogether, as it was the case with phlogiston theory. Alternatively, one could modify the text, which is what happened in the episodes of Cannizzaro's clarification of the atomic weight. Finally, one could re-interpret the experience in light of the existing language, which is what Ludwig Boltzmann did to resolve the specific heat anomaly. Boltzmann, while neither adding nor modifying any concept in the language of physics of his time, used the concept 'degrees of freedom' introduced by James Clerk Maxwell and re-interpreted the behavior of anomalous gases in a way that resolved the specific heat anomaly.[80] In all of these cases, it is not only impossible to determine or prescribe in advance which of the three options should be chosen. Also it is impossible to specify in advance how precisely either of the three

79 See Baumberger, Beisbart & Brun (2017), pp. 26f.

80 For a detailed analysis and discussion of this episode from scientific practice, see de Regt (2017), pp. 205–216.

options will be executed. If the text is dismissed, how will the phenomenon be accommodated? Through a new text and if so, what will that look like? If the text is modified, how is it modified and what will it look like in the end? If the phenomenon or experiences is re-interpreted, what will the new interpretation be? How individuals handle hitherto unknown situations, solve unknown problems, or understand new phenomena can never be known in advance, even if they use the same conceptual framework. The understanding individual herself and the other members of her community can only assess her understanding retrospectively with regard to the grammatical rules of their language and its success in accommodating the experience in question.

Concerning the third aspect, the possibility of misunderstanding due to modified or different conceptual frameworks, every conceptual framework might be wrong in fundamental ways, as Polanyi recognizes. Humans construct conceptual frameworks because they strive to discover truths about the world, and through the storage of a great amount of information in language, more and more details of the world can be recognized, analyzed, and, ultimately, understood. Concepts that persist over a long period of time have proven to be successful in many instances. However, no concept will ever be immune to revision. Languages improve, concepts are changed or added to accommodate new experiences better.[81] These changes in language reflect the changes, and possibly even the degrees, of understanding. For example, the language of phlogiston theory has been abandoned by chemists. From our contemporary perspective, chemists who understood combustion through phlogiston theory completely misunderstood the phenomenon, since we know nowadays that phlogiston does not exist. However, whether an individual understood or misunderstood is a matter of context. Phlogiston theory was very successful for almost 75 years and its proponents had some good empirical justification to apply and to defend it. They had reasons to assume that phlogiston exists and that the theory brought them closer to reality. When phlogiston theory has been developed, no one could know that it is false. This had to be discovered

81 This idea is comparable to the concept of epistemic iteration that Hasok Chang introduced. Based on his discussion of the development of thermometry, Chang argues that ""epistemic iteration is a process in which successive stages of knowledge, each building on the preceding one, are created in order to enhance the achievement of certain epistemic goals. … In each step, the later stage is based on the earlier stage, but cannot be deduced from it in any straightforward sense. Each link is based on the principle of respect and the imperative of progress, and the whole chain exhibits innovative progress within a continuous tradition." Iteration provides a key to understanding how knowledge can improve without the aid of an indubitable foundation. What we have is a process in which we throw very imperfect ingredients together and manufacture something just a bit less imperfect." Chang, H. (2004), *Inventing Temperature: Measurement and Scientific Progress*, New York, Oxford University Press, DOI: 10.1093/0195171276.001.0001, p. 226.

over time.[82] The language of modern chemistry is different than its predecessors in the 17th and 18th century, and this change in language accompanies and mirrors the gradual nature of understanding.

Episodes of revised conceptual frameworks and the accompanying understanding can, of course, be found in other disciplines, too. Consider, for example, de Regt's case study of early quantum physics and the rivalry between Erwin Schrödinger and Werner Heisenberg regarding the construction of an adequate theory of the structure of atoms. Schrödinger's wave mechanics represented the atomic structure in terms of wave functions, which was a very different form of articulation compared to Heisenberg's theory of matrix mechanics. Matrix mechanics did not represent atomic structure directly, but rather described relations between observable quantities like frequency or intensities of spectral lines. Additionally, Heisenberg formulated his theory in the mathematical language of matrices, with which most physicists were not familiar in the early twentieth century. That is, Heisenberg used a different language, a different articulate interpretative framework, than Schrödinger, while both were concerned with the same phenomenon, namely, the atomic structure. As a result, they judged each other's theory as unintelligible. Also, both theories were not without problems in accommodating known atomic phenomena, which again encouraged further critique by both parties against the opposing camp. It was Wolfgang Pauli, a companion of Heisenberg and supporter of his theory, who claimed that the new theory, or conceptual system, of matrix mechanics first has to be learned by everyone in the physical community, that the conceptions employed in the new theory must be understood, before it can be successfully used. Ultimately, the work of Schrödinger and Heisenberg has been combined and resulted in the theory of quantum mechanics that is known and taught today.[83]

4.2.3 Understanding is the ability to make sense of a phenomenon

Given the fundamental difference between knowing-how and knowledge-that, in this section I aim to show that understanding is a kind of knowing-how because, in alignment with Ryle and Polanyi, understanding is a gradual and multi-track disposition whose manifestations are context-sensitive. The concept of propositional knowledge as being something like justified true belief cannot capture what we associate with understanding, namely some competence of making sense of a situation, create a meaning, or yielding new information. How does this notion of understand-

82 For a detailed discussion of the merits of phlogiston theory, see Chang, H. (2012), *Is Water H_2O? Evidence, Realism and Pluralism*, Dordrecht, Springer, DOI: 10.1007/978-94-007-3932-1.

83 For an extensive and detailed discussion of this case study from physics, see De Regt (2017), chapter 7.

ing fit with my definition of abilities developed in chapter 4.1? There, I presented the following definition:

> *x* is an ability if and only if *x*
>
> i. is a disposition to perform a cognitive or physical activity successfully with respect to relevant standards,
> ii. has been learned and trained in a specific social context, and
> iii. manifests in processes that are partially tacit (i.e. that can never be made fully explicit).

The notion of understanding sits well with this. First, understanding is a disposition to perform a cognitive activity, namely making sense of a phenomenon through aligning language with experience. The match of language and experience must adhere to the non-formalizable standards upheld by the respective community without consciously reflecting on them. Second, those implicit standards are learned through participation in a community. By being raised and trained in a language, in a cultural community, humans learn how to use and speak the language, and to modify it to accommodate or manage new experiences. However, not just any modification or manipulation of symbols is allowed. Every language prescribes rules about its use that have been implemented due to their past success. Any modification of language must be plausible in light of the rules of grammar and of the experience is shall accommodate. The interpretation arrived at by the individual's understanding must make sense in light of the language, the theory of the universe, and the empirical evidence. Since the development of language serves the human striving of arriving at an ever more precise and accurate comprehension of the world, the rules that guide the use of a language serves this superior goal as well. Therefore, every member of a community agrees to respect the rules of a language, internalize and act upon them. However, the rules themselves are not valid eternally, but rather susceptible to change if they cannot accommodate (some) experience at all. The rules that govern the use and modification of a language depend on the specific context of the community. Hence, these rules can only be learned and internalized if one is a member of the respective community. Humans learn how to bring language and experience into accordance with one another by interacting with other, already versed individuals. Novices, both in science or in everyday life, learn and train how to understand phenomena under the guidance of teachers and supervisors. Teachers and supervisors assess whether the understanding of a phenomenon that students acquired is adequate. When the students demonstrated that they arrived at an adequate understanding often enough, it will be determined that they successfully acquired the ability to understand particular phenomena in the world. And third, the

manifestation of understanding is partially tacit for the subject, may it be a student or any other, more experienced person. While the person is consciously aware of the phenomenon, the situation, or experience she wants to understand, she is not aware of all her mental performances through which she ultimately conciliates experience and language.

After arguing in section 4.1 that abilities are dispositions to succeed, I suggested throughout this section that understanding could be conceptualized as an ability, a disposition to succeed in making sense of some phenomenon or experience. Whenever a subject understood something, she will have manifested the ability to understand by creating some meaning of the phenomenon that is acceptable given the respective standards. But how exactly do subjects do this, how exactly is understanding manifested? I provide an answer to this question in the next section.

4.3 The manifestation of scientific understanding

In the previous two sections, I developed and defended a definition of ability and argued that understanding fits this definition of ability. Now, if we accept this and take understanding to be an ability, a disposition to succeed, how exactly is understanding manifested? I already claimed that understanding manifests in aligning language with experience, but can this be spelled out in more detail? That is the task to which I shall now turn. In section 4.3.1, I address a prominent concept in the literature on understanding, grasping, and clarify what I mean with this notion. Following that, I argue why, in addition to grasping, articulating an explanation is necessary for (scientific) understanding in section 4.3.2 by drawing on Michael Polanyi's work on articulation and Mark Newman's model of understanding. This also is a clarification of the necessary relation between scientific understanding and scientific explanation, for which I argued in chapter three. In sum, I argue in this section that scientific understanding is manifested in the process of grasping relation of a phenomenon and articulating these relations as explanations. Importantly, my claims in this section are intended to cover scientific understanding, understanding gained in science, and not necessarily all kinds of non-scientific understanding. Neither do I claim that all kinds of understanding are manifested through grasping relations and articulating explanations, nor that only scientific understanding is manifested through grasping relations and articulating explanations. However, an analysis of a categorization of types of understanding that are manifested in this way and those that are not is a topic for further research and not covered by this book.

4.3.1 Grasping relations

When we consider possible manifestations of the ability to understand, one candidate that can be considered is grasping. The notion of grasping is ubiquitous in the debate on understanding and closely related to discussions about abilities in the context of understanding. Quite many scholars try to clarify what understanding is by reference to the notion of grasping. To my knowledge, Jonathan Kvanvig, whose view I presented in detail in section 3.3, was the first who gave grasping a prominent role in his analysis of understanding. According to him, "to understand is to grasp the variety of […] connections [between pieces of information]."[84] Unfortunately, it remains unclear what Kvanvig means exactly when he talks about grasping, as he does not elaborate this term any further. If "grasping" is used merely as another term for "understanding" without any further explication, the mere introduction of this term will not lead to any insights about understanding. Hence, several different and partly conflicting accounts of grasping are offered by various scholars.[85]

Before I address different views of grasping, let me emphasize the one common and basic assumption that unites all the different views of grasping. Whatever grasping might be in the end, grasping is taken to demarcate understanding from knowledge. Baumberger, Beisbart & Brun provide a nice example that elucidates this basic idea:

> Suppose that a climate scientist explains to her young son that the global mean surface temperature has massively increased since the middle of the 20th century because of increasing greenhouse gas concentrations. Since she is right and her son has good reasons to believe her explanation, he may be said to know why the global mean temperature has increased. But he does not seem to understand why. When asked why this is so, all he can do is to repeat his mother's explanation. The problem seems to be that he does not really grasp the explanation. But what exactly is he lacking?[86]

It is the answer to the question raised at the end of the example on which scholars working on understanding disagree, but they do not disagree on the problem. Here, I present two different interpretations of the notion of 'grasping', the "naturalistic view" and the, to put a label on it, "grasping as abilities"-view. I will argue that the "naturalistic view" of grasping is more plausible.

A basic insight of naturalists is provided by Daniela Bailer-Jones, namely that "understanding has a subjective component, in addition to the publicly accessible

84 Kvanvig (2009), p. 96.

85 For a good overview of different accounts of and controversies concerning grasping, see Baumberger, Beisbart & Brun (2017), pp. 12–17.

86 Ibid. p. 12.

component represented by explanation, in the sense that understanding takes place in an individual's mind."[87] Michael Strevens thinks along similar lines. He takes grasping of a correct scientific explanation of a phenomenon to be necessary for understanding this phenomenon and views grasping as a "fundamental relation between mind and world, in virtue of which the mind has whatever familiarity it does with the way the world is."[88] On that basis, Reutlinger et al. conclude that grasping is a philosophically primitive notion, i.e. that it does not matter for a philosophical analysis of understanding that grasping cannot be clearly defined. Since they take this to be a task for cognitive scientists, they call their view of grasping the "naturalistic view". However, what is important for philosophical accounts of understanding is that grasping is the subjective component of understanding, that grasping allows for some epistemic accessibility of a phenomenon for scientists, or subjects more generally. Grasping is taken to be a fundamental relation between mind and world.[89] Therefore, grasping (having epistemic access to) a phenomenon is a necessary condition for understanding it, but grasping is not identical to understanding.

However, this is not the only view on grasping. I call an alternative conception the "grasping as abilities"-view. Christoph Baumberger argues that "grasping the causes or reasons why p […] is better spelled out in terms of having certain abilities that are not required for simply *believing* that the factors in question are the causes or reasons why p."[90] The possession of knowledge depends on certain abilities, too, like memorizing and quoting information, but these are not the abilities that are necessary for understanding.

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87 Bailer-Jones, D. (1997), *Scientific Models: A Cognitive Approach with an Application in Astrophysics*. Ph.D. Thesis, University of Cambridge, p. 122.

88 Strevens, M. (2013), "No Understanding without Explanation", *Studies in History and Philosophy of Science A*, 44 (3), pp. 510–515, DOI: 10.1016/j.shpsa.2012.12.005, p. 511. It should be noted that Strevens adopts an ontic conception of explanation. That is, he views explanations as physical entities that exist in the causal structure of the world. The ontic conception of explanation is opposed to the epistemic conception of explanation, according to which explanations are representations of phenomena in the physical world. So for Strevens, grasping a scientific explanation means that a subject grasps an actual causal process in the world, and not merely a representation of that process. See Strevens (2008), p. 6. In contrast to Strevens, I endorse an epistemic conception of explanation. This fundamental difference aside, Strevens and I agree on a basic notion of grasping in the sense that (aspects of) phenomena in the world have to be grasped, and not merely an explanation in the sense of a representation, if a subjects wants to gain understanding of the phenomena in question.

89 See Reutlinger, A., Hangleiter, D. & Hartmann, S. (2018), „Understanding (with) Toy Models." *British Journal for the Philosophy of Science*, 69 (4), pp. 1069–1099, DOI: 10.1093/bjps/axx005, pp. 1082–1085.

90 Baumberger (2011), p. 73.

Baumberger suggests that for having understanding "why p (where q is why p) then [one is] (to some extent) able

> i) to comprehend and render an explanation of p which shows (e.g. by means of a generalization) how p depends on q,
> ii) draw the conclusion that p (or that probably p) from the information that q, and
> iii) for some p* and q*, similar but not identical to p and q, draw the conclusion that p* (or probably that p*) from the counterfactual assumption that q*, and, counterfactually assuming that p*, explain it with the help of q*."[91]

If the aspired understanding is not limited to grasping the causes or reasons for a phenomenon, the grasping of different or more dependency relations amounts to more of the same abilities that are already necessary for understanding the causes of a phenomenon, according to Baumberger.[92] Steven Grimm adopts a similar view on grasping as Baumberger and describes grasping dependency relations as "being able to "see" or anticipate how varying the value of one of the variables will lead (or fail to lead) to a change in the value of another variable. What this grasp involves is thus the ability to make modal inferences or to "see" into modal space."[93] Both Baumberger and Grimm view grasping to encompass other and possibly several different reasoning skills. For Grimm, grasping involves (at least) the ability to make modal inferences, whereas Baumberger takes grasping to include comprehending and providing an explanation as well as making varying kinds of inferences, as I state above.

What shall we make of these two different conceptions of grasping? I argue that the naturalistic view of grasping is more plausible than the "grasping as abilities"-view. Bailer-Jones correctly points out that understanding takes place in the minds of individuals and I argued in section 4.2 that understanding is taken to be an ability to make sense of a situation, create a meaning, or yield new information. Hence, it is plausible to conceive understanding as a cognitive ability that is manifested in our minds. Therefore, the manifestation of understanding is a cognitive process as well. However, as we often wish to understand phenomena, things, or situations that take place outside of our minds, in the world, we need to establish some connection between our minds and the things we want to understand. If we do not do this, I would not know how it should be possible to understand anything outside of our minds. Here grasping comes in. For an account of understanding, it is sufficient to think of grasping as getting epistemic access to a phenomenon. The metaphors of 'seeing, recognizing, or becoming aware of' relations of phenomena in the world might be instructive here. This view is in accordance with Strevens and Reutlinger et

91 Ibid. p. 73.

92 See ibid. p. 79.

93 Grimm (2017), pp. 216f.

al., who identify grasping as having epistemic access to the object of understanding. Hence, I am also taking a naturalistic stance on grasping. If we want to understand phenomena in the world, we need access to them. When a person grasps a relation, this relation somehow catches the attention of the person, it gets into her focus. She somehow recognizes that there is something interesting or relevant about the phenomenon that she wants to understand. And it only happens in the next step, after recognizing that some relation is there, that the person applies modal, counterfactual, inductive, deductive or analogue reasoning to make sense of the relation that has just been grasped. I take grasping to be a process that precedes and is distinct from other reasoning processes. I do not view grasping to be a composition of reasoning skills, as Baumberger and Grimm argue, because a person cannot make modal inferences or reason about something that she is not aware of at all. Individuals first need to grasp something they should or could reason about, before they can actually reason about it. Without establishing a relation between mind and world, without grasping, no reasoning about things could ever begin. Hence, grasping is worth to be taken as a distinct process.

In sum, grasping is the process of getting epistemic access to relations of the phenomenon that shall be understood. But what about explanation? I argue in chapter three that understanding requires explanation, but my conception of grasping as 'seeing' relations does not capture or include explanation. This problem can be solved in taking grasping to be only a partial manifestation of understanding. The complete manifestation of understanding requires grasping relations of the phenomenon as well as articulating explanations of the phenomenon. I address the second component of the manifestation of understanding in the next section.

4.3.2 Articulating explanations

How to flesh out the idea that articulating explanations is a necessary component of the manifestation of understanding? Michael Polanyi, again, provides helpful insights on this matter, when he investigates the role of articulation for scientific thought.

Humans rely on articulate interpretative frameworks as representations of complex situations to assist and guide their actions. Applying an articulate interpretative framework to a situation decreases the amount of mental work that a subject has to invest for analyzing a situation. Humans do not need to explore any new situation in all its complexity because the articulate framework already provides an interpretation of the situation, so Polanyi argues.[94] Therefore, the subject can almost immediately pass on to solve a specific problem in the given situation, without spending much time and energy to make sense of the situation in the first place.

94 See Polanyi (1962 [1958]), p. 76.

> Moreover, by being prepared to speak in our language on future occasions, we anticipate its applicability to future experiences, which we expect to be identifiable in terms of the natural classes accredited by our language. These expectations form a theory of the universe, which we keep testing continuously as we go on talking about things. So long as we feel that our language classifies things well, we remain satisfied that it is right and we continue to accept the theory of the universe implied in our language as true.[95]

The ability of using language in thought enhances the intellectual powers that humans possess. And Polanyi identifies several levels of articulation. The highly specialized scientific nomenclatures, symbolic operators or numerical denotations are expansions of ordinary speech that enable scientists to master even more complex situation or problems. Articulation enables systematization and manageable records that assist memory as well as speculative imagination because the crucial aspects of any situation can be presented in a comprised form through articulation.[96] "Articulation pictures the essentials of a situation on a reduced scale, which lends itself more easily to imaginative manipulation than the ungainly original."[97]

This 'theory of the universe' is already implied in the sense perceptions, according to Polanyi. Perception serves animals as well as humans to find their way around in the world, to find food or avoid threats. That is, perception provides us with the clues that we need to solve problems we are confronted with in everyday life. We trust our perception and experience to convey the things in the world to us in the way the things really are. Perception already establishes a 'theory of the universe'. Using language and applying words to objects or situations that we have already identified through our perception is an extension of that 'theory of the universe' that we already possess. Through language, it is possible to develop clearer and less ambiguous conceptions of the universe, and the various objects it comprises.[98]

Verbal and other linguistic pointers aid and enhance our mastery of any issue we are confronted with because they enable us to manage massive amounts of experiences and information. However, Polanyi does not argue that we stick to any articulate framework forever after we had learned it. On the contrary, he analyses how language is susceptible to re-interpretation.[99] Since the world and our experience of it are constantly changing, the meaning of language and the conceptual framework we are applying in a specific situation will also be modified with every new instance in which it is applied. We seek to achieve more clarity and precision in our

95 Ibid. p. 83.

96 See ibid. pp. 86ff.

97 Ibid. p. 88.

98 See ibid. p. 100ff.

99 I mentioned this point, too, in section 4.2 and illustrated it with examples of new articulated frameworks in chemistry and physics.

language as well as in our experience in order to find solutions for problems we are confronted with. Any modification or re-interpretation of an articulated conceptual framework is done owing to our hope of getting closer to reality. And modifying, re-interpreting, or even learning a language in the first place does change our ways of thinking. Polanyi holds that the modification of a conceptual framework is a subsidiary process that takes place while we focus on the situation we are dealing with. If a conceptual change proves to be successful, it will get established in the framework and transmitted to other member of the community who will continue to use the modified conceptual framework.[100]

In short, Polanyi argues that the use of language rendered the intellectual achievements of humankind possible. Humans are able do deal successfully with complex problems or situations, because our knowledge of the universe is stored, presented and used in the form of articulated language. Language assists thought; it enables sophisticated thought processes that would not be possible without the use of language as a guiding interpretative framework. This is the reason why humans, some of which are scientists, cannot make sense of phenomena without using language. Humans are driven by an "urge to understand experience, together with the language referring to experience. […] While our thoughts are of things and not of language, we are aware of language in all thinking […] and can neither have these thoughts without language, nor understand language without understanding the things to which we attend in such thoughts."[101] That is, we cannot understand anything in the world without thinking in our respective language, and scientists cannot reason about newly discovered relations or aspects of the world without using language.

A very similar line of thought can be found in the work of Mark Newman, who provides an example that illustrates the difference between *knowing an explanation* and *understanding the phenomenon that is presented by this explanation*:

> Muons […], which have a proper lifetime of only 2.2×10^{-6} seconds, can last the longer travel time of 333×10^{-6} seconds as they traverse from the upper atmosphere to the earth's surface. How is this possible?
> Explanation e_{muon}: muons are elementary particles which travel at 0.999978 times the speed of light. Entities that travel this fast are subject to the time dilation effect of Special Relativity. Time dilation is given by the relation: $\Delta t = \Delta t_0 / 1-(u^2/c^2)$. Where Δt is change in time in Earth's reference frame, Δt_0 is change in the proper time of the muon, u is the muon's speed and c is the speed of light. Doing the cal-

100 See Polanyi (1962 [1958]), pp. 108–111, 118–123.

101 Ibid. p. 106

culations we find that although it initially seems impossible, muons can actually last long enough to survive the journey.[102]

A competent English speaker with working memory who reads this explanation and comes to believe it will *know* this explanation of the lifespan of muons. But simply knowing, remembering and even re-stating or re-formulating this explanation in a linguistic sense does not amount to *understanding* the phenomenon of the lifespan of muons. What is necessary for gaining understanding of muons with this explanation is knowledge of the meaning of the concepts that are included in the explanation, not merely understanding the propositions linguistically. Only if one knows what a reference frame, proper time, and the time dilation equation *mean* can one really understand the lifespan of muons. According to Newman, knowledge of an explanation can be identified with a linguistic understanding of an explanation, whereas understanding of the phenomenon, which is presented by an explanation, requires conceptual knowledge of the 'deep meanings', as he calls it, of the concepts involved.[103]

How is it possible to achieve this conceptual knowledge of the deep meanings of concepts? Newman offers a first possible answer by referring to Conee and Feldman[104] and proposes that background beliefs are necessary in order to really understand an explanation. An expert, in contrast to a novice, has a robust set of background beliefs concerning the concepts used in an explanation. Therefore, the expert is in a position to categorize these concepts and make sense of the explanation as a whole. However, having the relevant background beliefs, i.e. knowing the meanings of the concepts, is not sufficient for an account of understanding the phenomenon. Additionally, the expert also has to appropriately *use* these background beliefs. If she does not do so, her understanding, if we attribute some understanding at all, will only be a result of lucky guessing and she will not be justified in accepting her understanding.[105] Importantly, abilities play a crucial role in Newman's model as well and his demand that relevant background beliefs must be possessed as well as used to understand a phenomenon is in line with Polanyi's analysis of the necessary interplay between articulate and inarticulate intelligence in the process of making sense of, understand, phenomena in the world.

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102 Newman, M. (2017), "An Evidentialist Account of Explanatory Understanding." In Grimm, S. R., Baumberger, C. & Ammon, S. (eds.), *Explaining Understanding. New Perspectives from Epistemology and Philosophy of Science,* pp. 190–211, New York and London, Routledge, pp. 192f.

103 See ibid. p. 193. Gilbert Ryle formulated and investigated a similar question: "What […] is the difference between hearing what a speaker says and making sense of what he is heard to say?" Ryle (1949), p. 51.

104 See Conee, E. & Feldman, R. (2004), *Evidentialism: Essays in Epistemology*. Oxford, Oxford University Press, DOI: 10.1093/0199253722.001.0001.

105 See Newman (2017), pp. 193ff.

Newman's model of understanding, which he calls the "Inferential Model of Understanding" (IMU), includes the following concepts:

> (K) Knowledge of an explanation is an accurate, justified representation of the explanation's propositional content.
> (U) Understanding an explanation is achieved when the representation of an explanation's propositional content is internally connected by correct inferences.
> (UT) S understands scientific theory T iff S can reliably use principles P_n constitutive of T to make goal-conducive inferences for each step in a problem-solving cycle, which reliably results in solutions to qualitative problems relevant to that theory.[106]

My focus lies on (K) and (U). Newman identifies knowledge of an explanation (K) with having linguistic understanding of the explanation. If this is achieved, the subject will have grasped[107] the meanings of each proposition that is involved in the explanation. She will be able to represent the explanation that reflects this grasping. If a person has explanatory understanding (U), she will have linguistic understanding and, *additionally*, link the explanation with correct inferences by exercising default reasoning. This is an implicit, tacit process. Newman takes the concept of default reasoning from the work on mental models in cognitive psychology. The basic idea is that our mental representations are built on rules. These rules are stimulated by default expectations that we take to be correct as long as we have no counterevidence. For example, when we see a black cat, we activate a set of rules that constitute the concept "black cat" and we stick to this mental representation until we gain perceptual evidence that, in fact, what we are seeing is a small black dog instead. The first implicit reasoning process, the expectation and rule-activation, is what Newman calls "default reasoning". This form of reasoning is said to govern most of our everyday reasoning.[108]

The abilities that keep K and U apart are correct inferences by using default reasoning. They are a form of knowing-how, according to Newman. Since he treats knowing-that and knowing-how as non-reducible, a view that accords with the discussion I present in section 4.1, these abilities are not a form of propositional knowledge. In order to gain (U), we need to recognize the appropriate relations as well as the relata presented by the explanation. A necessary prerequisite to do so is to know generative relations like "allowed", "caused", "created", "forced" or "generated". For

106 Ibid. p. 199. I am mentioning UT here for the sake of completeness, but I will not address it in further detail.

107 Newman uses the term 'grasping' without clarifying what he means with it. I use Newman's terminology here, although his notion of grasping might not be identical to my notion of grasping that I present in the previous section.

108 See ibid. p. 200.

every explanation, the correct generative relations between the explanandum and (parts of) the explanans have to be chosen. One single explanation might include several different generative relations and for every step in the explanation, the correct relation has to be used. If a person fails to do so, she will not have understood the explanation. Take again the explanation of the lifespan of muons. Amongst other things, it is stated in the explanation that "Time dilation is given by the relation: $\Delta t=\Delta t_o/1\text{-}(u^2/c^2)$." A novice will not understand the explanation if she takes this relation to be causal. It is not the case that a change in the earth's relative time causes a change in proper time. Rather, the relation presented here is a sufficient condition and this has to be recognized by the novice. Therefore, the abilities to know and select the appropriate generative relations are an essential difference between knowing and understanding an explanation.[109]

However, this is not the whole story yet. Newman goes one step further and argues that, in addition to recognizing generative relations, an explanation schema for these relations has to be articulated. An explanation schema is a type of cognitive structure that is defined by a set of generative relations. Take the two generative relations "eating generates growth" and "greater size generates slower movement", which are used to articulate the following explanatory schema to explain the extinction of the dinosaurs: "The dinosaurs ate a lot which caused them to grow enormously, which slowed their escape from predators, which caused their extinction." This is an example of an explanatory schema, although an incorrect one. In this case, some appropriate generative relations have been recognized, but not all of them are appropriate. As a result, the person who constructed and articulated this explanatory schema does not understand the extinction of the dinosaurs because she failed to infer the correct generative relation between explanans and explanandum.[110]

The difference between knowing an explanation and understanding it presented by the IMU model of understanding is summarized by Newman as follows:

> IMU adopts the idea that explanatory understanding (U) surpasses the cognitive achievement of knowledge (K) in virtue of the subject activating not only appropriate generative relations from memory, but also articulating those relations in the correct explanatory schema. Without these skills we may come to understand linguistically what is being said, but fail to insert the appropriate relations or relata, and hence fail to explanatorily understand.[111]

The work from Polanyi as well as from Newman suggest that the articulation of an explanation is the second part of the manifestation of understanding, which follows

109 See ibid. pp. 202f.

110 See ibid. p. 203.

111 Ibid. p. 203.

the grasping of relations of the phenomenon. As I take grasping to be a process that is distinct and prior to other reasoning processes, I also demarcate articulating an explanation from other reasoning processes. I do so because the possession and successful manifestation of various reasoning abilities does not automatically amount to the articulation of an explanation. The case of James Clerk Maxwell who tried to make sense of the specific heat anomaly, which I mentioned already in section 4.2.2, is a good example to illustrate this point. Maxwell possessed impressive reasoning and calculating skills. He even introduced a completely new concept, the 'degrees of freedom', in order to make sense of the phenomenon. He realized that the available language of physics cannot accommodate the specific heat anomaly, which is why he introduced the concept 'degree of freedom'. And the concept 'degree of freedom' would be meaningless if Maxwell could not relate it to something in the physical world, in this case, the kinds of motions of molecules. However, despite all his efforts and accomplishments, Maxwell was not able to articulate an explanation of the specific heat anomaly, although he grasped that the phenomenon has something to do with the kinds of motion that the gas molecules exhibit and spent years of his life thinking about and trying to solve the issue. Maxwell contributed groundbreaking achievements to physics, like his classical theory of electromagnetic radiation and his equations for electromagnetism, which sufficiently proof his exceptional reasoning skills, but the specific heat anomaly remained a mystery to him.

In contrast to Maxwell, Boltzmann was able to make use of the available concepts and articulated an explanation of the specific heat anomaly through his dumbbell model. Boltzmann's success might have been due to the extended articulated conceptual framework, which included the concept 'degrees of freedom', that neither Clausius nor Maxwell had at their disposal, at least not from the beginning of their investigations. In Polanyi's view, Boltzmann would never have had the thought processes that ultimately led him to the development of his dumbbell model if he had not had the concept 'degrees of freedom' at his disposal. Without this concept, Boltzmann could not have reasoned with it and could not have formulated an explanation of the specific heat anomaly in terms of degrees of freedom. As Polanyi argues, scientists learn the sophisticated and specialized language of their discipline during their education. That is, scientists think about the phenomena they try to understand in terms of the specific language that they learned. And this language might change when deficiencies are recognized, as in the case of the research on the specific heat anomaly, where the articulate conceptual framework was extended by Maxwell to include the concept 'degrees of freedom'. And in Newman's account, Boltzmann would never have identified the relation between the specific heat anomaly and the degrees of freedom, if the concept 'degrees of freedom' did not exist and, hence, could not be a candidate for a relatum.

Grasping relations of phenomena in the world and articulating them in form of explanations are the two components of the manifestation of (scientific) under-

standing. Importantly, in my usage the term 'articulating' refers to the construction of an explanation in an individual's mind, and not to any form of expressing or communicating. An individual cannot express or communicate any explanation if she has not articulated this explanation in her mind beforehand. However, I do think that as soon as a subject articulated an explanation in her mind, she will be able to communicate this explanation in some way to other subjects. And since instances of understanding are grounded in a fundamental principle urging subjects to discover truths about the world, subjects who understood something will also want to communicate the explanation she articulated. By making an articulated explanation publicly accessible, her understanding is publicly accessible and can be scrutinized by other subjects. In doing so, a subject can get additional justification and support that she understood something correctly, that she discovered some truth.

4.3.3 The manifestation of understanding

To sum up, I argued in this section that grasping relations of a phenomenon and articulating these relations in form of explanations are the manifestation of scientific understanding. Together, grasping and articulating manifest understanding. Grasping denotes the process of gaining epistemic access to the phenomenon that shall be understood, the process of 'seeing' or 'recognizing' some relation of the phenomenon. Subsequently, the subject that grasped some relation of the phenomenon will resort to the conceptual framework she uses in order to represent the grasped relation in form of an explanation.

Since understanding manifests in the process of grasping and articulating explanations, understanding a phenomenon is a procedural ability. The procedural manifestation of understanding is partially tacit for the subject. She will not be able to explicitly state how exactly she gained understanding of a phenomenon, why or how certain observations or data caught here attention, how she grasped a relation she did not know before and how she articulated an explanation of the grasped aspect of the phenomenon by using the specific language she possesses. The ability to understand phenomena is an instance of inarticulate intelligence. However, when a subject gained understanding of the phenomenon, she will be able to make explicit what she understood. That is, she will be able to express the explanation she articulated since the manifestation of understanding relied on the vocabulary of her language. If a person looks at an orrery, she might gain understanding of the planetary motion in our solar system without having explicit access to how exactly she was able to grasp information represented by the orrery. But once she gained understanding of the apparent retrograde motion of mars, to return to an example from Peter Lipton discussed in section 3.1, she can express and communicate what she understood since she thought about the represented phenomenon in the vocabu-

lary of her language. That is an instance of articulate intelligence, the construction of an explanation, which is grounded in inarticulate intelligence, in understanding.

4.4 The inextricable relation between understanding and knowledge

What is understanding? Is understanding an ability or a type of propositional knowledge? And if understanding is an ability, how is it manifested? Those were the questions I set out to answer in this chapter. I started with an analysis of the concept 'ability' and developed a definition of ability as dispositions to perform a cognitive or physical activity successfully with respect to certain relevant standards, which have been learned and trained in a specific social context and whose manifestations are partially tacit. This definition of ability accommodates performed activities of subjects that are often or usually labelled skillful, for example athletic or artistic performances, and also theoretical activities like logical reasoning or calculating. I then argued that understanding itself should be regarded as an ability to make sense of a phenomenon, a situation, or an experience, and that such a conception of understanding does not conflict with my argument developed in chapter three that understanding requires explanation. The process that manifests understanding consists of two partial processes, namely grasping relations of the phenomenon that one tries to understand and articulating the grasped relations in form of an explanation.

Why should understanding be viewed as an ability and not as a form of propositional knowledge? Because one and the same phenomenon or experience can be understood in various different ways, using different languages and arriving at different interpretations. Ptolemy understood the motion of heavenly bodies differently than Copernicus, Lavoisier understood combustion differently than proponents of phlogiston theory, and Schrödinger and Heisenberg understood atomic structures differently before they integrated their languages to arrive at a more precise interpretation. All of these individuals have two features in common. First, all of them understood the phenomenon they wanted to understand. They arrived at an interpretation of the phenomenon that accommodated the language they used and the worldly situation they had access to, they were able to make sense of the phenomenon. Second, all the mentioned individuals were striving for truth. All did their best in light of their resources, their language and experience, that they had at their disposal to discover truths about the world. That Ptolemy was wrong in seeing the earth at the center of the universe could only become apparent when our language and our experience of the world developed and with the help of more sophisticated instruments or measurement devices. Whether someone understood or misunderstood a phenomenon can only be assessed in light of a specific context but the ways in which a phenomenon can be understood, how language and phenomenon

are conciliated, are countless and cannot be explicitly articulated or predicted in advance. This is different for knowledge. Either ones knows *that p* or one does not, and *that p* can be explicitly stated. Knowledge is not gradual, multi-track, and context-sensitive in the way understanding is. Merely possessing knowledge does not enable a subject to master and combine her language and the phenomenon to which it is applied. Knowledge, in its classical formulation, is justified true belief. A belief is something completely different than the demanding activity of understanding. This differentiation between understanding and knowledge does not only fit Ryle's distinction between knowledge-how and knowledge-that, with which I started this chapter, but also the view from virtue epistemologists that knowledge is an intellectual success achieved through ability.

Understanding is an ability to make sense of experiences, situations, or phenomena in the world, to solve arising puzzles concerning them. Understanding is the ability to generate new knowledge, knowledge that captures the interpretation of an experience that an individual made. We cannot articulate or communicate the understanding itself, that is, how we managed to grasp a relation and articulate this relation in an explanation because it is an ability. But what we can, do, and sometimes even should articulate and communicate, is the result of our understanding, the phenomenon that we have understood, and the interpretation of the phenomenon we arrived at through understanding. In order to understand something that lies outside of our minds, we need to get some access to the thing we want to understand. This happens through the process of grasping relations of the phenomenon or situation. Grasping can be described as recognizing a relation that might have something to do with the thing we want to understand. However, merely grasping relations in the world is not sufficient for understanding because grasping, in the way I conceptualize it in section 4.3.1, does not entail the ability to make sense of what has been grasped. This happens through the articulation of the grasped relation in the vocabulary of a language. Thus, understanding requires grasping relations as well as articulating explanations. Once we arrived at an interpretation of a phenomenon, once we managed to bring our experience and our language into accordance, we arrive at the belief that our interpretation represents a true aspect of the world. We arrived at a justified, possibly true, belief. We generated knowledge. However, holding a justified true belief is something completely different than the ability to grasp relations in the world and articulate them in explanations, that is, to conciliate experience and language and generating new knowledge by ourselves.

Why is it unproblematic and no contradiction that understanding is an ability, a type of knowledge-how, which requires explanation, which is a type of knowledge-that? The potential conflict that could be assumed here dissolves as soon as it is realized that understanding and knowledge (of explanation) are inseparably intertwined and develop only in conjunction with one another. Based on an extensive discussion of Polanyi's account of the relation between inarticulate and articulate

intelligence, I argued that knowledge and understanding necessarily go together because humans cannot make sense of a phenomenon in the world without resorting to the language of the culture in which they were raised and trained. Understanding is an ability and its manifestation, grasping and articulating, is partially tacit and inaccessible to us. This is because we are focally aware of making sense of the phenomenon that we want to understand, we are concentrated on what we observe or measure of the phenomenon, while parallel to our focal attention we subsidiarily make sense of what we perceive, observe of the phenomenon we investigate, by reference to our language. We cannot articulate our understanding, that is, how we actually managed to manifest the ability, to make sense of a phenomenon that we investigated, how we grasped specific relations or constructed generative frameworks. But in this tacit process of understanding a phenomenon we resort to explicitly articulated and non-tacit resources that our language provides and apply these resources to the phenomenon. This is the case not only for scientific understanding, which his achieved by using the sophisticated and formalized language of the respective discipline, but also for non-scientific understanding. Lay people understand the world in terms of the language they grew up with. Although the process of gaining understanding of a phenomenon, of arriving at an adequate interpretation through the manipulation of our language, respects certain context-sensitive criteria that guide the permissible use of a language, these criteria do not prescribe any concrete procedure of how one should gain understanding or at which interpretation one should arrive in the end. In short, knowledge-that is required for manifesting understanding, a type of knowledge-how, and through understanding knowledge-that gets expanded, improved, or revised.

Where are we now? After arguing in chapter three that scientific understanding requires explanation, I argued in this chapter that (scientific) understanding is an ability that is manifested in the process of grasping relation of a phenomenon and articulating these relations as explanations. While my argumentation in chapter three is exclusively targeted at scientific understanding, my analysis in chapter four is broader and addresses understanding in general. Although these two different foci of my investigation do not result in a conflict, as I hopefully showed throughout this chapter, one might still doubt whether the conception of understanding I put forward is actually able to capture understanding gained in science. So far, I worked myself through various arguments and developed my own. And yet, the best and most consistent argument loses its relevance if it cannot be related to what is happening in the world. Hence, it is time to look at science itself and see whether my conception of scientific understanding can withstand scientific practice. In the next chapter, I turn to an episode from biology, the introduction of zebrafish as a model organism, and analyze how scientists gained understanding of the genetic regulation of vertebrate development with the use of zebrafish.