SOME CONSIDERATIONS ON UNDERSTANDING THROUGH MODELS AND SIMULATIONS

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Abstract: The subject of scientific understanding was only recently considered in regard to models and simulations. In the present paper I will address some aspects related to this issue. In the first part, after reviewing the ways the topic of scientific understanding appeared in philosophy of science, I will point to some characteristics that should be reconsidered in order to approach understanding in a modeling context. In the second part I will challenge a distinction which attempts to separate the particularity of understanding provided through simulations from the one provided through theoretical models. In the last part I will address some worries related to the distinction between proper understanding and the illusion of understanding with reference to simulations. I will argue for the fact that there are no stronger reasons to consider simulations more vulnerable than models to the dangers of fake understanding.

Keywords: understanding, models, simulations, theoretical versus pragmatic understanding, proper understanding versus sense of understanding.

Scientific understanding is a major epistemic goal of scientific endeavor as important as scientific explanation. Though a neglected topic in philosophy of science, the importance of understanding was recently reconsidered. This reconsideration comes in the context of an increased interest in a closer contact with scientific practice and of the dismissal of any sort of approach that would try to make science fit some prior vision[1]. One of the bolder expressions of this tendency can be found in the rejection of a theory-centered type of philosophy of science, the sort of approach that dominated the field during the last century. The rejection was implemented and driven by an increased interest in the topic of models and modeling activities[2].

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[1] Nick Huggett provides a characterization of the actual tendency in philosophy of science which he describes as localism (N. Huggett, *Local philosophies of science*, Phil. Sci. **67**, Supplement. Proceedings of the 1998 Biennial Meetings of the Philosophy of Science Association. Part II: Symposia Papers, p. 128–137 (2000)).

[2] Autors like N. Cartwright, R.I.G. Hughes, M Morrison, St. Hartmann, P. Humphreys are the main figures of this orientation that shows its impact in the field in the recent issues of the major specialized journals that were dedicated to the subject.

The aim of this paper is to discuss some aspects of scientific understanding as related to models and simulations. In the first part I'll look to the topic of scientific understanding as it was approached in philosophy of science and identify some characteristics of this approach that have to be reconsidered in order to approach it in a modeling context. In the second part I will discuss a distinction proposed by J. Lehnard that attempts to identify the specificity of understanding provided by simulations. In the last part I'll discuss some worries raised by Kuorikoski related to the distinction between a proper understanding and the illusion of understanding.

TRACKING THE TOPIC OF SCIENTIFIC UNDERSTANDING IN PHILOSOPHY OF SCIENCE

The topic of scientific understanding was a rather neglected subject in philosophy of science despite its association with the well-known topic of scientific explanation. The main reasons for this neglect could be found primarily in the antipsychologist attitude which marked the classical conception of neopozitivism that set the agenda of the field. A direct formulation of this attitude can be found in Hempel's work on explanation: "such expressions as 'realm of understanding' and 'comprehensible' do not belong to the vocabulary of logic, for they refer to psychological or pragmatic aspects of explanation"[3]. These aspects were considered by the neopositivists to belong to the context of discovery and not to the one of justification[4].

Hempel distinguishes also a "theoretical or cognitive sense of understanding" that is provided by explanations by "exhibiting the phenomenon to be explained as a special case of some general regularity"[5]. In another well-known characterization, an explanation gives us understanding by showing that the occurrence of the phenomenon to be explained "was to be expected". Besides these claims, there is no explication of understanding in his work. This reticence is driven by the conviction that such aspects are only psychological by-products of explanation.

The modeling topic was also considered to fall with predilection into the context of discovery. Models were seen primarily as additional means, deployed for various purposes such as theory construction or theory extensions in new areas of application or theory confirmation. One of the roles they were given was to make more intelligible the abstract theoretical principles[6]. They would enhance our

[3] C. G. Hempel, *Aspects of Scientific Explanation: And Other Essays in the Philosophy of Science*, New York, Free Press, 1970, p. 413.

[4] The distinction was intended by Reichenbach to delineate the proper domain of logical-philosophical analysis from other aspects that fall outside the scope of such an analysis such as the psychological, sociological or historical factors.

[5] *Ibidem*, p. 257.

[6] R. B. Braithwaite, *Scientific explanation: a study of the function of theory, probability and law in science*, New York, Harper Torchbooks, 1953, p. 23.

understanding by making use of more familiar concepts. Such are for example the mechanical models for electrical phenomena in the XIXth century physics before the development of electromagnetism theory or the actual drop model for the atomic nucleus in nuclear physics. More generally, "making things more familiar" was considered by some authors, as for example W. Dray[7], to be the defining mark of explanation and understanding in science. Nonetheless despite the recognition of its role in different contexts there was no systematic attempt to articulate any approach on understanding due mainly to the negative attitude already mentioned.

In the frame of the explanation debate Michael Friedman[8] was the author that argued for a reconsideration of understanding for a philosophical approach. By distinguishing the subjective part of pragmatics, i.e. the one that refers to personal psychological factors, from the objective one that refers to rational beliefs and attitudes of more persons, he sees no impediment in giving understanding a place in the philosophical analysis of explanation. According to Friedman, an account of explanation should capture the objective aspect of understanding by isolating a specific propriety of the explanatory relation that is independent of historical variations and has a demonstrable connection with understanding. This propriety is the one of unification. In his words "science increases our understanding […] by reducing the total number of independent phenomena that we have to accept as ultimate or given"[9] and thus unifying the corpus of our knowledge. The reduction process involves the derivation of the phenomena expressed through general regularities (previously independently accepted) from more comprehensive laws. For illustration we can consider the case of the derivation of some specific physical laws as: Kepler's law, Galileo's laws, the laws of kinetic theory of gases, from the general laws of Newtonian mechanics.

Through his account Friedman initiates the unification approach to scientific explanation and sets also the characteristics that will mark the view on scientific understanding. The first major one is the global character that he attributes to understanding. In his words understanding is a "global affair"[10], meaning that it doesn't concern isolated facts or events but the unification of a multitude of phenomena. It involves integration of phenomena in a larger corpus. Adherents of the unificationist view on explanation will articulate this integration in different accounts: either through explanatory patterns as in Kitcher's account[11] or through relations between sets of models as in Bartelborth[12] account. For W. Salmon[13] this understanding is expressed through entire world-pictures that science can provide us.

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[7] W. H. Dray, *Laws and Explanation in History*, Oxford, Oxford University Press, 1960.

[8] M. Friedman, *Explanation and Scientific Understanding*, Journal of Phil. **71**, 1, 5–19 (1974).

[9] *Ibidem*, p. 15.

[10] *Ibidem*, p. 19.

[11] Philip Kitcher (*Explanation, conjunction, and unification*, Journal of Philosophy **73**, 8, 207–212 (1976), p. 212) states that "science advances our understanding of nature by showing us how to derive descriptions of many phenomena, using the same patterns of derivation again and again."

[12] T. Bartelborth, *Explanatory unification*, Synthese 130, 1, 91–107 (2002). He develops his account in the frame of the structuralist approach on theories – a variant of the semantic view on

The second characteristic is the closer link between understanding and explanation. In Friedman's view an account on explanation should tell us also what understanding is and how it is reached. Approaching understanding is possible only through an approach on explanation and not in a direct way, making it therefore a sort of a by-product of an account on explanation. Only two decades later we can find authors that articulate a direct approach on understanding. Such is for example Schurz's account[14] that still retains the global feature of understanding and still connects it to explanation but the last one becomes derivable from his conception on understanding. A more recent direct account was proposed by de Regt and Dieks[15] that articulates a pragmatic conception of understanding in which the main idea boils down to the ability to draw qualitative inferences without performing detailed computations.

These two characteristics were the most explicit ones that marked the way understanding was considered to be approachable for most of the authors who touched the subject. Especially the second feature is implicitly adopted by all the authors including the ones who adhere to other conceptions of explanation such as the causalist view (Salmon) or the contextual one (van Fraassen, Achinstein).

UNDERSTANDING IN A MODELING CONTEXT

If we are to approach understanding as provided by models and simulations these two features have to be reconsidered. They seem to be inadequate for describing understanding at the model level for some reasons that I'm going to discuss below.

Regarding the first one the main reason lies in the fact that models are local constructs, exhibiting a different nature than theories or other larger units of scientific knowledge. They are scientific constructs that are more context-bounded and purpose-driven. In contradistinction to theories, pragmatics plays an important role in model building and model application. The recent literature on the roles and nature of models emphasized this aspect. Authors like R. Giere, M. Morrison, N. Cartwright, or St. Hartmann[16] are important figures in a recent trend that promotes a less theory-centered philosophy of science and argue for the reconsideration of the important roles models and modeling processes play in science. All the above authors emphasized the pragmatic character of models. In Giere's definition on

scientific theories – as developed by Balzer, Moulines and Sneed (W. Balzer, C.U. Moulines, J. D. Sneed, *An architectonic for science: the structuralist program*. Dordrecht, D. Reidel Pub. Co., 1987).

[13] W. C. Salmon, *Causality and Explanation*, Oxford, Oxford University Press, 1998.

[14] G. Schurz, *Explanation as unification*, Synthese **120**, 1, 95–114 (1999).

[15] H. W. Regt, Dennis Dieks, *Contextual Approach to Scientific Understanding*, Synthese 144, 1, p. 137–170 (2005).

[16] A sample of this philosophical orientation could be found in the volume edited by Morgan and Morrison, *Models as Mediators. Perspectives on Natural and Social Science*, Cambridge University Press, 1999.

model-based representation, the intentions and the purposes of the scientists are essential for model's nature. Such a representation involves a subject S that uses a model X to represent an aspect of reality W for some purposes P. Models are constructs more sensitive to the context of inquiry. In a recent paper Simpson[17] makes this point bolder arguing for the idea that models and simulations are entirely observer relative: "models and simulations are what they are because of how we see and use them."[18]

This bold pragmatic character makes model-based understanding to be a more restrictive one, a more local one as it is determined in a higher degree by the context of investigation. Nevertheless this observer relativity as Simpson advocates does not invalidate understanding as an object of philosophical investigation, as a totally subjective matter in Hempel's footsteps. Friedman's claims discussed in the first section retain their validity in this situation too. The integrative feature of understanding is a persistent characteristic, only that we have to reconsider it accordingly. Such an understanding would imply a restricted sort of unification that corresponds to a local kind of integration[19]. The integration would not range unrestricted over entire scientific fields, disciplines or corpuses of knowledge. In constructing a model only some selected information is integrated and this selection is mainly determined by contextual factors. Such are the type of representations we use that determine what sort of idealizations and simplifications are involved according to the purpose for which we build the model.

Regarding the second characteristic, I think that a model-based approach on explanation pushes us more in the direction of a pluralistic view not only regarding explanation but also understanding. A major consequence of the explanation debate is the fact that the majority of philosophers admits the existence of an irreducible variety of explanatory forms. This is still less clear in regard to understanding, due mainly to the reduced interest in the topic and the lack of debate around it.

Friedman's requirement to closely connect explanation and understanding such that only an account on explanation can tell us what understanding is, appears to be too restrictive in a modeling context. A simple analysis of the relation between explanation and understanding shows more ways of casting it than the classical constrain of understanding as a product of explanation. In a recent paper Peter Lipton[20] shows convincingly that there are more cognitive benefits associated with understanding that can be obtained without explanation. For Lipton "understanding is more extensive and more varied in its sources than those who

[17] J. Simpson, *Identity Crisis: Simulations and Models,* Simulation & Gaming 42, 2, 195–211 (2011).

[18] *Ibidem*, p. 196.

[19] The need to consider a local type of unification was also emphasized by other authors such as V. Gisjbers, *Why unification is neither necessary nor sufficient for explanation*, Phil. Sci. 74, 4, 481–500 (2007).

[20] P. Lipton, *Understanding without Explanation,* in *Scientific understanding: philosophical perspectives*, H. Regt, S. Leonelli, K. Eigner eds., Pittsburgh, University of Pittsburgh Press, p. 43–63 (2009).

would equate explanation with understanding allow."[21] This claim becomes more vivid and better substantiated if we consider model-based understanding. The variety of representations and the variety of purposes associated with models are the major sources that induce variation in the relation between explanation and understanding.

Peter Lipton identifies four types of benefits that we can obtain without explanations: causal information, that we can get through observation, experimentation, manipulation or inference, a sense of necessity provided through the fact that the process could not have been otherwise, a sense of what is possible that can come even from potential or false explanations and the unification obtained by comparing phenomena through analogies and classification. These could be pursued in the frame of different non-explanatory types of models that are built for such specific purpose. A direct approach on understanding will among other be able to account for these cases in which models are used to give us some sort of understanding without articulating an explanation.

An additional observation finds its place here. Taken into account this plurality of forms, different scientific contexts might require different ways to construe understanding. The classical construal of understanding as a product of an explanation seems proper with reference to explanatory models. Another construal that seems to be useful for a larger range of models is one that sees understanding as a sort of ability. This interpretation goes back to Wittgenstein, for whom understanding is attributed according to whether somebody can reliably perform some activity. Applied to the scientific activity one might construe understanding provided by a model as an ability to draw inferences by making use of it. Though some authors[22] took it as a general construal, I think that the chances to have a universal model of understanding are slim. The morals from the explanation debate and the faith of the general accounts on explanation should make us more cautious in trying to hunt for such an account.

THEORETICAL UNDERSTANDING *VERSUS* PRAGMATIC UNDERSTANDING

Till now I haven't made any reference to the possible differences between models and simulations. In the literature such differences were mentioned being related especially to the temporal aspects and the methods of solving[23] characteristic for models and simulations. Nevertheless models are constitutive of

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[21] *Ibidem*, p. 44.

[22] J. Kuorikoski, *Simulation and the Sense of Understanding*, http://philsci-archive.pitt.edu/4480/, (2009); J. Kuorikoski, *Simulation and the sense of understanding*, in P. Humphreys, C. Imbert, eds., *Models, Simulations and Representations*, London Routledge, 2011; D.A. Wilkenfeld, *Understanding as representation manipulability*, Synthese 190, 6, 997–1016 (2013).

[23] See Grune-Yanoff and Weirich, *The philosophy and epistemology of simulation: A review*, in *Simulation & Gaming* 41, 1, p. 20–50 (2010), for a review on this issue.

simulations and many times the scientists do not separate them sharply. In philosophy of science it is therefore less clear[24] if they should be treated separately or not in regard to different matters. I will further tackle this issue in regard to understanding.

Below are some questions that arise in connection to understanding through simulations: What kind of understanding do we reach through simulations? How is it different from understanding through models? What could be a proper construal for an approach on understanding as provided by simulations? Is this construal suitable for all kinds of simulations independent of the field of research and application? My discussion with reference to a specific distinction proposed by Lehnard[25] will touch on some of these questions but not necessary in order to get a final answer for them; rather to identify the issues hidden behind them and the search for such adequate answers.

A recent account that explicitly looks at the possible distinction between the kind of understanding gained through models and one from simulations was proposed by J. Lehnard. He develops the distinction with reference to an example from nanoscience, which involves the behavior of materials at nanoscale. In a first experiment a nickel tip is crushed into a gold surface; by removing it slowly a thin wire of gold atoms is generated. Though the component particles are governed by the laws of motions specific for atomic level, equations are too complex to be solved in order to obtain an analytical solution for the nanoscale dynamics. Simulations are used with the aim to explore the collective behavior and new patterns of behavior emerge which take the form the generation of the wire. The unexpected result surprised the scientists. The phenomenon was only some years later confirmed through experimental work.

In the simulation the relation between the laws implemented as rules and the emerging behavior remains opaque. Humphreys[26] called this aspect the "epistemic opacity" of simulations. We lack any theoretical insight that is usually given through a theoretical model into the way the nanoscale behavior emerges. Instead of creating a highly idealized model, the simulation "squeezes out" (as the author puts it) the consequences of the situation in an unintelligible way. The authors describe the situation as very similar to an experiment in which a new effect is discovered and isolated.

Lehnard claims that we have to deal in this case with a new type of understanding which he calls pragmatic understanding. It results for the effort to overcome the "complexity barrier" that blocks the theoretical knowledge. Understanding through simulations involves manipulability and controlled intervention, it is a kind of understanding by control. This sort of understanding is quite different, according to Lehnard, from the theoretical understanding, one build in the frame of

[24] *Ibidem*.

[25] J. Lehnard, *Surprised by a Nanowire: Simulation, Control, and Understanding*, Phil. Sci. (PSA 2004) 73, 5, p. 605–616 (2006).

[26] P. Humphreys, *The philosophical novelty of computer simulation methods,* in *Synthese* 169, 3, p. 615–626, (2009).

a theory under the guidance of the laws. This type was the one advanced by the theory-based view on explanation. Unlike pragmatic understanding, the theoretical one is linked intimately to intelligibility, which is seen here as the theoretical insight gained through such an understanding.

I will further challenge this distinction and try to show that if we tackle it in more detail it becomes rather problematic. The hidden asperities might be seen as incentives for a further needed reflection on how to properly approach the issue of understanding in models and simulations.

Taken into account Lehnard's view, it seems proper to regard understanding provided through simulations under the ability construal. Manipulability and intervention are specific for simulations but they do also characterize in essential way some types of models. The most obvious ones are the material models that can be found in different scientific disciplines. Such are the scale models from engineering or organism models from biological sciences. In such models we engage in controlled interventions and try to identify some relations or some effect. The similarity is especially interesting with the model organism where the resulted effect emerges at a different level of organization than the one where the intervention takes place. In a typical biological experiment at molecular level one knocks out a gene and searches for an effect in the phenotype. The biologist overcomes this way in a similar way to Lehnard's example a "complexity barrier". The complexity arises from the great number of interactions and the variety of molecular mechanisms that intervene between genes and the phenotype.

The possibility to manipulate and intervene is a defining feature in case of simulation and material models. Nevertheless one can find this possibility in theoretical models too; one might engage in manipulation of constitutive elements in theoretical models as well. A similar form of manipulation that involves changing the values of parameters in order to search for the effect induced is to be found in models as in simulations. In contradistinction to simulation we have in models' case some theoretical expressions that connect the parameters with the effect-variable. Nonetheless we might say we gain some sort of pragmatic understanding too alongside the theoretical one.

What Lehnard points to as theoretical understanding is one that we derive from the possibility of embedding the models in a larger theoretical frame, the one of the theory, since they are theory-based models. Such models impart understanding of the system under investigation because they subsume its behavior under the laws of a theory. But I cannot see any reason why theoretical understanding would exclude the existence of pragmatic understanding.

The existence of the pragmatic sort of understanding becomes more evident if we consider Woodward's account of scientific explanation. His account links explanatory knowledge to the capacity to intervene on and manipulate the phenomenon inquired. According to his account explanations consist in exhibiting functional dependencies between variables. He endorses a counterfactual setting of the explanatory situations. Explanatory relationships provide understanding by giving answers to what-if-things-had-been-different questions, which concern the consequences of counterfactual of hypothetical changes in values of the explanatory variables. So according to this account a theoretical model has explanatory potential in the way it captures these intervention patterns.

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We could regard the issue discussed from the opposite perspective, the one that will look at potential theoretical intrusions in simulations. As in case of theoretical models, simulations make recourse in their building to knowledge and understanding provided through a theory. One could object by claiming that it is rather the underlying model of the simulation but not the simulation itself that is built in such a frame. The distinction is real but it does not meet our point. Regarding the matters of understanding we do make recourse on this theoretical frame. Understanding the simulation engages the conceptual resources of the underlying models and in fact of the theory under which it is built. The emerging pattern of a simulation makes sense and so provides some sort of understanding only in the larger frame that delineates the problem that is addressed.

But the point on theoretical intrusions can be made stronger. A recent paper by Grüne-Yanoff[27] argues for a special way of casting the explanatory virtues of an agent-based simulation. The example refers to a simulation that has as outcome the population dynamics of specific social group of Native Americans (the Anasazi Indians). The entry data constitutes of paleoenviromental information for the time period studied; the rules of behavior are taken from the ethnographic studies of similar populations (since the modeled population lived 700 years ago). According to Grüne-Yanoff the simulation offers a type of functional analysis and a potential functional explanation. This explanation is explicated by using Cummins' account on functional analysis. Unlike the traditional account on functional explanation where the existence of a component is explained by recourse to the function it plays in the system, for Cummins it is the capacity of the system that is analyzed in terms of the capacities of the component subsystems.

Under such a construal a simulation ceases to be totally unintelligible. The above case suggest we might have to take into account the differences between various simulations according to the domain of application. Drawing on the two examples used, one from nanoscience and one from agent-based modeling, most probably there is a variation with the scientific context in which they are deployed and the problem supposed to be addressed. In case of the nanoscience example the simulation bears a stronger similarity to an experimental setting in which new phenomena are discovered and isolated. The pragmatic type of understanding appears to be the boldest one. In case of the agent-based simulation of Anasazi society, the simulation engages more evident a theoretical dimension. The possibility

[27] T. Grüne-Yanoff, P. Weirich, *op. cit*.

to manipulate the system by controlling its parameters and consequently the pragmatic understanding is not of a major importance. The scientist is not interested in this case in the experimental nature of the system, in isolating new phenomena. The real population dynamics is already known. The interest is in the modality we can reproduce this dynamic in our system, approach as close as possible the real pattern of population evolution.

According to Grüne-Yanoff this analysis provides us with potential functional explanations of the system. The afferent understanding engages rather a theoretical dimension that the pragmatic understanding from the nanoscience example, though it is not delivered by the fact that it was articulated in the frame of a theory.

So we might say that a theoretical understanding of some sort is not to be excluded when considering understanding through simulations. It can accompany the sort of pragmatic understanding we claim in this case. Neither is a pragmatic sort of understanding given through manipulation and intervention totally devoid of theoretical insight. The distinction that Lehnard draws might not work as smoothly as intended. For sure we have to look in delimited situations at specific types of models and of simulations in order to substantiate more the difference between understanding gained from models and from simulations.

PROPER UNDERSTANDING *VERSUS* THE SENSE OF UNDERSTANDING

A last issue that I would like to discuss is related to the distinction between genuine and fake understanding or as it was referred by some authors between proper understanding and the sense of understanding. J.D. Trout[28] voices a bold critique against the sense of understanding that explanation conveys as a cue to a correct explanation. He accuses philosophical theories of explanation to rely on this sense as a criterion for goodness of explanation.

The sense of understanding originates in two psychological biases and is a false guidance to epistemic progress. The two psychological biases are well documented in studies of cognitive psychology. They are hindsight and overconfidence. The hindsight-bias is expressed by “I-know-it-all-along effect” in which people tend to overestimate how probable the event was before it occurred. It gives us a false understanding of an effect and makes us regard the search for an explanation as complete. Overconfidence makes us overestimate the correctness of our beliefs. As an effect, it could also prompt a stopping rule for pursuing further explanatory inquiry.

Trout argues from a naturalistic position drawing directly on psychological studies. Other philosophers as Michael Scriven[29] also warned on the dangers of

[28] J. D. Trout, *Scientific explanation and the sense of understanding*, Phil. Sci. 69, 2, p. 212–233 (2002).

[29] M. Scriven, *Explanation, Prediction and Laws*, in *Minnesota Studies in the Philosophy of Science 3*, p. 170–230 (1962).

confusing the sense of understanding with the proper understanding without identifying its psychological origins. Not all philosophers agree on Trout's diagnosis. H.W. Regt, who proposed a philosophical theory of understanding and engaged in a heated debate with J.D. Trout, thinks that Trout's attack is on a strawman since no author will intend to base its theory of understanding on these psychological features.

From a more mundane perspective one can notice that the two biases seem to have multiple roles in the metal life of the investigators. On one side they can induce the feeling of understanding without the underlying proper understanding as Trout emphasizes. On the other side they could play stimulative roles[30] by giving immediate cues to scientist to conduct their research and contribute to their motivational drive. They are a constant presence associated with cognitive processes and there is no issue in eliminating them but in how to guard against their negative consequences. As I've argued in another place[31], the scientific cognitive endeavor has the necessary resources to effectively guard against these biases.

Returning to the distinction between the proper understanding and the sense of understanding, it is important to discuss it esp. in the context of modeling and simulation activities. Though it is not clear in what sense simulations provide us explanations[32], they do contribute to our understanding and therefore are subjects to the same danger of fake understanding. Kuorikoski addressed the issue of the illusory understanding in case of simulations. For him the ability to create understanding is an important criterion in the "assessment of simulation technique" and this fact emphasizes the importance of addressing the ways that can fake the understanding. For him this danger is esp. severe for simulations. He proceeds in identifying some specific situations that are conducive to such inadequacies. In the following paragraphs I will discuss his worries and address the severity claim. I will try to show that models are equally exposed to such dangers and that simulations are not more vulnerable to them.

A first situation Kuorikoski discusses that could lead to a fake understanding is one in which we mistakenly confuse the understanding of some sub-operation for the understanding of the process. As Frigg and Reiss[33] emphasized, simulations are in principle understandable due to the simple basic rules which they incorporate. The danger lies in the way one may extrapolate this sense of understanding to the entire process. According to Kuorikoski modelers would be immune to such dangers. Contrary to his claim, I think modelers are confronted with the same sort of dangers.

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[30] As Kourikoski, *Simulation and the Sense of Understanding*, http://philsci-archive.pitt.edu/4480/ (2009), also noticed.

[31] In my doctoral thesis: R. David-Rus, *Explanation and Understanding through Scientific Models. Perspectives for a New Approach to Scientific Explanation*, PhD. diss., University of Munich, 2009.

[32] For a recent review on the issue see Weirich and Grune-Yanoff, *op. cit*.

[33] R. Frigg, J. Reiss, *The Philosophy of Simulation: Hot New Issues or Same Old Stew?*, in *Synthese* 169, 3, p. 593–613 (2009).

Knowing and understanding the sub-operation that constitute a model does not mean one understands the model as a whole. The argument from the complexity of the inferences in simulations does not hold since the inferential task in a model might be complex as well. In analogy to the simulation situation, knowledge of the rules of mathematical calculus or algebraic theory does not automatically guarantee the understanding of the final results or of the model as a whole.

But probably we need to clarify what would mean to understand the model as a whole. This will imply or be closely connected to understanding its purpose, its use and its significance for the inquired system. To illustrate the situation: a physicist can make use of the services of a mathematician for solving the equations in the model and the latter can be successful without understanding the result as related to the model explanatory and in its significance. Model-based understanding bears more than the simple understanding of sub-operations that are part of it. It essentially involves the relation between the model and the target system it stands for.

A second worry refers to the confusion between visualization and insight. Using visual means to make more vivid the results of a simulation is a common technique. Many times we can even see the process unfolding in front of us which increases our familiarity with the process. Such means enhance our sense of understanding which might be not backed by a proper understanding. Kuorikoski is right in pointing to the elevated risk present in this situation. But models can also be subjected to such techniques as it is quite often the case to search for a graphical representation of the modeling results. Kuorikoski discusses a specific model from ecology – the Lotka-Voltera model – which can be solved but its solutions can be represented graphically so we can visualize the dynamics of the populations.

It is possible to implements the same problem as the model addresses through a cellular automata simulation. As a result we will be able to watch the movie of the population dynamics directly. The oscillating patterns of population variation will be observed directly instead of being represented on a plot as in case of the model. Nevertheless both are visualizations of the studies process.

One might object that the most vulnerable to the dangers of fake understanding is in this case the non-specialist. Nonetheless the non-specialist does not have to be a layman; it might be a scientist from another scientific discipline. In fact the situation in which a biologist is impressed by the visual representation of a simulation is not such a rare event. The danger is exactly high for such areas of science in which visualization plays a major role in the research techniques. This is indeed characteristic for biological sciences.

A third worry is linked to the manipulativity of dynamics that can be confused with the understanding of the mechanism. As discussed earlier, knowledge of dependency between input and output variables provides the kind of pragmatic understanding mentioned by Lehnard. It can show why some results are as they are rather than something else. Kuorikoski rightly points to the fact that unless we clarify how this relation between variables is dependent on the structural features of the model we don’t have a real understanding of the system’s behavior.

But this applies rather to the models than to simulations since in the last case we do not have an explicit mechanism of its behavior. It is the explicit mark of some models to articulate such mechanisms. Knowledge of mechanisms that describe subsystems or sub-operations does not count since they will provide understanding only of the components' behavior but not of the system. We will this way be back to the previous worry.

A last worry is related to the idea of the maker's knowledge. It is the idea that one has to be able to build the thing in order to understand it. Quoting J. Epstein one of the main figures in agent-based modeling we can say "if we didn't grow it you didn't explain it"[34]. The issue seems to refer to simulations directly since "growing" appears to be specific for them. Nevertheless the metaphor is obscure not at least because it is not clear in what sense we explain or we understand by building something. We might grow a theoretical model too in the sense we unfold its logical consequences in a specific formal language. Casting the situation through Woodward's conception on explanation, building a system gives us some proficiency in answering what-if-things-had-been-different questions and so to provide explanation and understanding. But this does not guarantee that we understand the behavior of the system as a whole. As argued earlier this might be the case equally for models as for simulations.

In the end I want to point to two other reasons that might bring some additional light for my previous discussion. The first one draws on the variety of the modeling typology and modeling strategies. The range of model expressions is hard to be captured in a few delimited features. The different roles models can play in scientific inquiry enlarge also the modalities we might experience the sense of understanding. So the variety carries with it also a larger variety of ways of generating miscalibrated understanding. They might therefore not be more secure or shielded from this danger than simulations are. Such judgments are better fleshed out with reference to specific types of models. The type of model can fix the lines for the investigation of the potential dangers for building illusory understanding.

The last point I want to draw attention on has a general strategic flavor. It refers to the fact that we might go too far sometimes with the distinctions and end up with an overdistinction that places the investigation on a wrong track. The aspects related to explanation and understanding in simulations might be more closely linked to ones of the associated models. Judging these aspects could be better engaged in the larger context that includes a more defined models structure. What would be such models? It is first of all, the underlying model on which the simulation is built. In order to understand what are the questions to which the simulation provides answers and potential explanations we have to make recourse to the underlying models and its purposes. This places the simulations in the frame of the research problems and the larger context of the inquiry.

But there is also another modality that involves the construction of other models, i.e. metamodels that could make more explicit some of the explanatory claims

[34] J. Epstein, *Agent-based Computational Models and Generative Social Science*, in *Complexity 4, 5*, p. 41–60. (1999), p. 43.

of simulations. A metamodel is a representation at a higher level taking as a target system to be modeled the simulation itself. Such is for example the way we might represent a cellular automaton by a Markovian stochastic process[35]. In agent-based computational economics building metamodels for simulation is already a used practice. The main point suggested by these illustrations is that the investigation on the understanding provided by simulation gains consistency through such techniques.

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In order to draw to an end my discussion, I'll briefly review its main points and recall the main morals. In the first part I've engaged in a short review of the topic of scientific understanding as it was approached in philosophy of science. Though a neglected subject, it was placed in the frame of the major topic of scientific explanation and its approach was marked by two demands: an inherent global character and a close connection to explanation. In order to address the subject with reference to models and simulations I have argued that the two demands have to be reconsidered. On one side we have to make room for a sort of local type of understanding that accommodates the specific characteristic of modeling activities. On the other side we have to embrace a pluralistic view that makes room for the variety of relations that exist between understanding and explanations and decouples the analysis of one from the other.

In the second part I have addressed a distinction advanced by Lehnard that aims to identify the specificity of understanding through simulations. I've challenged his distinction by pointing to aspects that make problematic the separation between a theoretical kind and a pragmatic kind of understanding. The last one obtained through manipulation and intervention is not necessary confined to simulations; on the other side one might claim theoretical insights gained from simulations.

In the last part I discussed the distinction between genuine and fake understanding. Contrary to Kuorikoski's claims on this distinction applied to simulations, I have argued that we do not have stronger reasons to consider simulation to be more vulnerable than models to the dangers of fake understanding.

As a final remark on the topic, we have to admit that the novelty of the subject and the scarcity of existing analysis makes the inquiry into the subject a pioneering endeavor. The aspects discussed are among the few articulated ideas that were formulated on this topic. It is better therefore to proceed cautiously in such areas of research. Drawing on the experience from the previous philosophical debates, especially the one on explanation, we should guard against the dangers of misguided investigations and sterile debates. It is probable better to abstain at this point form grand generalizations and proceed stepwise in constant contact with scientific practice. The benefits of such a move could be valuable not only for philosophers but to scientists as well.

[35] C.R. Shalizi, C. Moore, *What Is a Macrostate? Subjective Observations and Objective Dynamics*, see http://philsci-archive.pitt.edu/1119/, (2003).