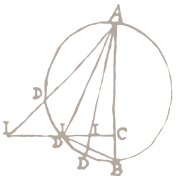

Introduction

*Appropriation and Transformation of Ancient Science**

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The transformation processes of scientific knowledge is the common subject of the four papers in this collection. The scientific knowledge they refer to is the knowledge originally codified during classical antiquity, either in the Hellenic or the Hellenistic period.

The four papers contribute to the fundamental thesis that up to the end of the early modern period the transformation processes involving ancient scien-tific knowledge were always grounded in 'experience of nature and materiality.'

The term 'experience of nature and materiality' is left deliberately vague and is best explained by means of a multilayered approach. The most fundamental layer is the perception and representation of nature and natural phenomena in different media, and the way in which this is done. While nature and natural phenomena are reliably stable, the attempts to describe and explain them enable knowledge to develop. This knowledge is always part of a knowledge system and the latter is continuously transforming. All the conceptions and theories used to explain how nature and reality are perceived are assigned to this first layer. This goes hand in hand with all the techniques developed to represent reality, such as painting, surveying, drawing techniques, and even geometric diagrams. In turn, the development of methods of representation

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* The fundamental subject of this collection of papers – the theory of the transformation of scientific knowledge – was initially investigated within the framework of a research group affiliated to the CRC 644 – *Transformations of Antiquity* and to Department 1 of the Max Planck Institute for the History of Science. The specific idea to develop a transformation theory that considers the role of materiality and practical knowledge was then discussed at length with Jürgen Renn, Harald Siebert and Matthias Schemmel. Finally, the four papers were presented in a session entitled "Experience as a Mechanism of Appropriation and Transformation of Ancient Science," held at the Annual Meeting of the History of Science Society in San Diego in 2012. Special thanks go to Lindy Divarci and Anna Siebold for their decisive and continuous support.

implies the formation and accumulation of particular practical technical skills as well as the possibility of using mathematics and geometry. The first three papers are case studies developed in the framework of this first layer.

Practical skills and practical knowledge represent the second layer which is best expressed with the term ‘materiality.’ It is well known that practical knowl-edge, for instance the knowledge of a shipwright or a machine-maker, remained remarkably stable over centuries and sometimes even over epochs, from antiq-uity to the end of the Renaissance. During these epochs, practical knowledge and technology were not closely connected to theoretical knowledge, as is the case in modern times where the former is mostly considered an application of the latter. In earlier times, practical knowledge and technology rather dic-tated the agenda of theoretical research, if any connection was established at all. Particular problems or accomplishments attained by means of accumulated experience may eventually have challenged certain theoretical aspects of the knowledge system of the same period. The process of accumulation of practical knowledge, therefore, often quietly unfolded over centuries, sometimes even successfully migrating from one culture to another. This second layer is the background against which transformation processes took place as the fourth case study of the present work shows concerning the early modern period.

To recapitulate, the processes of transformation of ancient scientific knowl-edge that occurred in later epochs were connected, if not driven, first by attempts of inquiring nature and second by practical activities. Due to the sta-ble character of nature and technology, inquiring them therefore constitutes a background that explains how on the level of logic and why on the level of history transformation processes can be defined as processes characteri ed by continuity. The link that causally connects materiality and transformation processes in history further implies that, when particularly intensive phases of production took place and because such phases were always in strong connec-tion with the development of practical knowledge, transformation processes were particularly impressive during these periods. From this perspective, it becomes evident that the booming economy of the early modern period, which was closely connected to an impressively developing technology, questioned the knowledge system of the time to such an extent that new knowledge was required and eventually formulated. This new knowledge relied on the trans-formation of those aspects of ancient scientific knowledge that had been even-tually neglected in the centuries immediately preceding the late Middle Ages and the Renaissance.

Transformation processes concern only codified knowledge. The codifica-tion of knowledge denotes a process of reflection and abstraction by means of which knowledge is made explicit. Concerning historical sources from antiq-

uity, such external representations of knowledge are mostly, though not only, written texts. If the framework is limited by the idea of scientific knowledge, then artifacts such as mathematical instruments or machines, and drawings such as geometrical diagrams or machine drawings, are also a part of such cod-ified knowledge.

The knowledge that becomes an object of transformation processes is always part of a particular knowledge system, which in turn can be best understood as a network of artifacts, instruments, codified practical knowledge, how-to descriptions, recipes, concepts, theories, and rules that are all interconnected. The transformation theory that underlines the four papers, therefore, is con-stituted by mechanisms affecting the formation and mutation of knowledge systems. Such mechanisms result from a series of historical processes that can-not be delimited by a systematic taxonomy. Apart from the case of text corrup-tion over time – the transformation process usually analy ed in the frame of classical philology – historical investigations, which are accomplished against the background of a transformation theory, focus for instance on processes of recontextuali ation of knowledge in different epochs or in the frame of differ-ent cultures. In all cases, transformation processes of ancient scientific knowl-edge have always involved only specific aspects of one knowledge system that were transformed within the framework of another knowledge system. When it is asserted for instance that the content of a work such as Hero of Alexandria's *Metri* was transformed during a later epoch, this always implies that the con-tent of that work was recontextuali ed in a new knowledge system so that it was then connected to aspects, results, research objectives, practices and problems different from those among which the work initially originated.

ne peculiar aspect of the processes of transformation is their close link to transmission history. Codified knowledge emerges, is continuously trans-formed over time and space, and finally can disappear, even forever. Trans-formation history is not the same as transmission history the former aims to investigate the causes of the transformation beyond transmission history, due, for example, to text corruption. ut ultimately, transformation history relies on transmission history. The spatiotemporal frame of each case study in trans-formation history does not depend on – but is identified by means of – the transmission history of the codified knowledge under consideration. Transmis-sion history helps to determine if, for example, an ancient work disappeared in a specific area in late antiquity and reappeared in the same area during the early modern period. This would indicate that the transformation process con-cerning scientific knowledge, codified in that particular work, was subject to discontinuity. Continuous transformation processes therefore took place out-side the discontinuities identified by transmission history along the time arrow.

Despite the continuity that characteri es processes of knowledge transformation and therefore the object of transformation history, from this perspec-tive the early modern period has often been identified as a distinctive epoch. Following the approach developed by Hartmut hme in *Transformation. in on ept ur rfors ung ulturellen andels* H. hme et al., München, 2011 , which is not limited to the scientific knowledge but embraces all aspects of knowledge and culture, it is possible to determine a sort of one-to-one relation between antiquity and the early modern period in Western culture. This is due to the fundamental historical fact that the very idea of antiquity as a specific epoch began with the work of the early humanists and was literally created between the late Middle Ages and the end of the early modern period. This creation process is in turn identified as a consequence of the process of trans-formation of ancient knowledge that took place during that period. As is well known, ancient knowledge played a decisive role in the process of formation of pre-modern science. This resulted from the sheer scale of the early mod-ern process of transformation of ancient science which assumed proportions never seen before and was in turn driven by the impressive expansion of the early modern knowledge network.
Since historical research has never abandoned the original idea of antiq-uity created during the early modern period, and because of the indisputable emergence of new scientific knowledge on a broad scale during that period, the impression indeed emerges that transformation processes are always characteri ed by such one-to-one relations ancient texts on one side and early modern scholars on the other and therefore not by continuity. However, if the perspective is enlarged, it is not difficult to recogni e that processes of transformation of ancient scientific knowledge were taking place all the time, though these processes did not result in the epochal periodi ation defined in the early modern period which, with a few mutations, is still in use today. Early modern processes of transformation of ancient scientific knowledge, though particularly relevant from the perspective of transformation history, nevertheless do not represent more than one, though distinctive, case among many other pos-sibilities.

In the paper “Experiencing Geometry in Roman’s Surveyors’ Texts,” Courtney Ann Roby examines the practice of surveying in the Roman Imperial period. This paper shows how surveying practices can be identified as a means of transformation of geometric theoretical knowledge of Hellenistic origins into a new structure of knowledge. Such new knowledge, codified in the works of two surveyors – Hyginus Gromaticus and albus – who lived between the first and the second century ce, was of a more practical nature and obviously

dealt with nature and its representations. evertheless, the new works were mathematically as precise as the original Hellenistic works. This knowledge was able to satisfy the urgent and diffuse needs of a rapidly expanding territory, as was the case for the early Roman Empire. Although land surveying is an older practice, it may be assumed that the relevance of such activities with regard to political and economic issues increased decisively during the time of the Roman Empire because of the increasing dimensions of the empire itself. As the expanding territories required administration, land surveying knowledge not only became a crossroad for different knowledge traditions and practices, but also an active transformative element among these traditions and practices. Due to the significance of their work, land surveyors were in fact increasingly requested to codify their knowledge and practices in treatises concerned with their discipline and activities. A process of abstraction and self-reflection was therefore set in motion, which constitutes the precondition to analy e the relations between surveying and other domains of knowledge.
The research clearly shows that the surveying activities of this period can-not be seen as a mere application of geometry. It rather shows how the prac-tice of surveying, while making explicit use of Euclidean geometry, also pro-duced new theoretical, geometrical knowledge. In particular, the argument shows that knowledge of land surveying was the result of multilayered and multidirectional transformative processes. Geometrical knowledge was trans-formed when applied to the observation of material territory, and the knowl-edge concerned with territories was transformed into geometrical categories. The knowledge of territories can in turn be seen as being multilayered as well because it concerns geological knowledge, which is related to the act of mea-suring and at the same time to administrative and legal constraints and objec-tives.

A further layer of knowledge is represented by the graphic representations of land surveying diagrams, records, and bron e tablets as associated with math-ematical, cartographical and legal administrative knowledge. The distinctive role of visual representations and, specifically, of diagrams in the ancient sci-entific works is analy ed in the paper “Thinking and Learning from Diagrams in the Aristotelian *Me ani s*” by Joyce van Leeuwen. In this case the trans-formation process concerns diagrams found in Greek manuscripts, from the y antine period, of the Pseudo-Aristotelian text *Me ani al roblems*. The analysis of the process then extends to the early modern period. *Me ani al roblems* is the first text, dating back to the 4th century bce, to deal with the-oretical mechanics in Western culture . With some exceptions the text was ascribed to Aristotle until the end of the early modern period. The text contains

a theoretical formulation by means of which the law of the lever is enunciated for the first time. Moreover, it is also a text that clearly shows the close connec-tion between technology in the form of practical knowledge and the theory of mechanics. The study demonstrates that the functions of the diagrams, whose presence characteri es this text over centuries, changed significantly from one epoch to the other. eginning with a closely connected explicative function in the y antine manuscripts, in the early modern period the role of the diagrams became more and more illustrative of the reality to which the Aristotelian mechanics was connected. Although many diagrams retained their geometric character, others served to recontextuali e the work in a different culture with different needs.
Diagrams not only display a specific interpretation of a text but also con-tribute, by means of additional content, to that interpretation as well. Given the impressive technological and economic developments of the early modern period, the transformation concerning the functions of the diagrams clearly indicates the fundamental role played by Aristotelian mechanics in this con-text. The early modern period shows the increasing awareness that mechanics, that is, the science of machines, resulted from such investments in technology.

As mentioned above, the most stable background against which transforma-tion processes occurred is represented by reality and by the perception of reality. The paper “Transformation of Euclid’s *pti s* in Late Antiquity” by Har-ald Siebert establishes the fact that the ultimate cause for the transformation of optics, and specifically of the knowledge codified in Euclid’s *pti s*, is the change in the conception of how human beings visually perceive things. Con-ceptions concerning the visual perception of human beings changed over his-tory depending on factors that transcend proper scientific practice. ltimately, such conceptions depend on how reality is defined metaphysically. However, it would be a mistake to believe that a metaphysical definition of reality was always given throughout different epochs, regions and cultures. In order to avoid anachronisms, it must be asserted that a specific conception concern-ing the visual perception of human beings depended on what reality meant for those who formulated it. The development of such conceptions, moreover, occurred independently from the existence of an explicit formulation or con-sciousness of the metaphysical tendencies that inspired a specific idea of real-ity. In the last instance, therefore, transformation is caused by the contact with the reality that is visually perceived. Moreover, the study shows that further experiences of practical nature can be used in favor of or against such concep-tions. In support of the extramission theory, for instance, according to which visual rays are emitted by the eyes, the commentator Calcidius used the phe-

nomenon of the electric discharge of the torpedo fish to explain the visual phenomenon, at least analogically.
Furthermore, more than one geometric model of vision could be and was developed, each depending on a specific conception. The geometric model of vision is the background against which a theory of optics is developed, as for instance Euclid's *pti s*. However, the formulation of a new geometric model of vision in history was never accompanied by a brand new theory of optics, but rather by a new version of the older theory, obtained by means of a transformation process. Concerning Euclid's *pti s*, in particular, Siebert's study shows how the *orpus* of the theory was maintained while its head –the definitions of the new geometric model of vision – were changed. The definitions, finally, are expressions of the principles that embed a conception of the perception of reality and therefore the contact with nature. The final result, therefore, no longer corresponds to *u lid s* ptics and what remains are sources concerning conceptions of vision and geometric models of different epochs, rather than of antiquity, because the original text is lost.
This study, more than any other, clearly shows how relevant the connec-tion between transmission and transformation history is, especially when the transformation process taken into account is a long and continuous one, as is the case here. The first three papers are based on profound philological research concerning the textual sources and linguistic aspects. They therefore create interesting examples of how classical philology and history of science can work together when the objective is related to historical epistemology, to which transformation theories belong.

The fourth study – "Ancient Pneumatics Transformed During the Early Mod-ern Period" – focuses on a case that is characteri ed by a long break in trans-mission history. In particular, it is concerned with Hero of Alexandria's work *neumati s*, which was substantially taken into consideration again during the early modern period following the diffusion of print technology. For this rea-son, this study also complements the framework of the transformation theory elucidated by Hartmut hme and described above. In this study, the philolog-ical analysis is limited to a short history of the early modern editions. n the other hand, this case focuses more strongly on the role of practical knowledge as a background for transformation processes. It shows how ancient practical knowledge, like that codified in Hero's *neumati s*, became part of the expe-rience and knowledge of the early modern engineers through a multilayered approach. The engineers evaluated the text from the perspective of aesthetics, design, composition, and technology. The final result was a selective accep-tance and recontextuali ation of the ancient work concerned with only those

subjects and aspects that had not yet been developed and or improved in the frame of the flourishing early modern technology. Finally, once this pro-cess had been accomplished, the theoretical foundations of *neumati s* – the theory and constitution of the elements and of matter – also became a central component in the theoretical debate, which in turn gave rise to the emergence of new knowledge that at once abandoned both the Aristotelian and the Hero-nian ancient conceptions.

Transformation processes are overlay structures created by historical investi-gations. Intentionality thus cannot be ascribed to the actual historical actors in the transformations. The intentions of such actors can only be recogni ed on a lower layer and identified with the aim to work within the frame of their own knowledge system, eventually taking into consideration works produced in earlier and or different epochs and cultures. The question concerning what the result of a transformation process would be was never formulated in the scientific practice of the periods under consideration.