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Nacherzeugung, Nachverstehen: A Phenomenological Perspective on How Public Understanding of Science Changes by Engaging with Online Media

Wolff-Michael Roth
University of Victoria

Norm Friesen
Boise State University, normfriesen@boisestate.edu

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Nacherzeugung, Nachverstehen: a phenomenological perspective on how public understanding of science changes by engaging with online media

Wolff-Michael Roth, *University of Victoria*
Norm Friesen, *Boise State University*

Abstract
It is widely acknowledged in science education that everyday understandings and evidence are generally inconsistent with the scientific view of the matter: "heartache" has little to do with matters cardiopulmonary, and a rising or setting sun actually reflects the movements of the earth. How then does a member of the general public, which in many areas of science is characterized as "illiterate" and "non--scientific," come to regard something scientifically? Moreover, how do traditional unscientific (e.g., Ptolemaic) views continue their lives, even many centuries after scientists have overthrown them in what are termed scientific (e.g., Copernican) revolutions? In this study, we develop a phenomenological perspective, using the Edmund Husserl's categories of *Nacherzeugung* and *Nachverstehen*, which provide descriptive explanations for our observations. These observations are contextualized in a case study using online video and historical materials concerning the motions of the heart and blood to exemplify our explanations.

Keywords
phenomenology; history; activity; passivity; learning paradox; common sense; scientific sense; Harvey; Descartes; heart; system view of blood circulation

1. Introduction—common sense and the learning paradox

> Precisely because *Nachverstehen* encounters the limit of nonpresentability—precisely because it is passive—it *must* be active. (Lawlor, in Merleau-Ponty, 2002: xxix)

This study was designed to provide a response to the question about how the general public can learn about the nature of science, about the process of coming to know by interacting with materials freely available on the Internet. Whereas the literature shows that school students frequently are turned off by and away from science (King and Ritchie, 2013; Swarat et al., 2012), people of all walks of life frequently express an interest in particular forms of science by engaging with popularized representations of scientific concepts, such as recent advances in genetic science, or the discovery of the Higgs-Boson particle, as reported in textual, audio-visual and other media (Roth, 2010). How do these people—as well as children in school— learn something from a YouTube clip that might involve the overturning of a long-held belief about the natural world? How do we move from everyday, common sense to the new, scientific sense of the world when the scientific sense is not *directly* derivable from what we already know? How can this new scientific sense be simultaneously unrelated to, *and* integrally grounded in this prior understanding? The problematic is framed in educational psychology as the "learning paradox" (Bereiter, 1985; Glasersfeld, 2001). It has not been satisfactorily solved in the literature on the learning of science, as the question of how a cognitive organism transcends itself by building new structures that move substantially beyond present tools, structures, and materials has not been adequately answered (Roth, 2012). Moreover, the associated question of how we come to learn something that lies beyond and outside our current horizon of comprehension while engaged informally with popularized media representations is not generally posed and even less frequently addressed (Roth, 2010). Despite an increasing number of studies that describe the use of online media to teach science concepts, there is a dearth of studies showing *how* people *learn* science generally and anatomy specifically from sources such as YouTube (e.g., Snelson, 2011; Jaffar, 2012).[1] In the literature on the popular or public understanding of science, the process of change in individual understanding itself rarely (if ever) is made problematic. Thus, for example, some authors employ a discourse of "diffusion and integration of scientific information into everyday thinking" (Courvoisier et al., 2013: 287); others theorize learning in the public sphere, as may occur at open-house events, in terms of categories of "consumption of scientific culture," "scientific consumption behavior," and the accumulation of cultural capital (Kato-Nitta, 2013); still others use references to the integration of diverse images and discourses (e.g. Locke, 2013).

In this article, we draw on the concepts of *Nacherzeugung* (re-production) and *Nachverstehen* (re-understanding) to descriptively explain how engagement with broadly educational materials, non-initiates undergo processes in which they effectively "re-live" the accomplishment of scientific principles out of pre-scientific understanding. *Nacherzeugung* literally translates as producing (*erzeugen*) something again (*nach*), and in this reproduction following someone else who has done this before. Similarly, *Nachverstehen* denotes the process of coming to understand in the way someone else has come to understand. Like the English words "after" or "following," *nach* can mean both "subsequently" and "according to." In the present context, these meanings refer to the process of transitioning from everyday, common sense to a scientific sense, and following or according to popularized representations of scientific findings. We use an analysis of a YouTube video and historical documentation associated with the first idealization or discovery of the modern scientific view of the operation of the heart and circulatory system. We do this to exemplify how everyday "folk" come to learn and become interested in science as they relive a transition from prescientific to scientific understanding. Here, we are not referring to the use of fiction to get students interested in such areas as biology or in issues such as human cloning, genetic

[1] A search of Thomson Reuters' *Web of Knowledge* yielded 1,058 articles with "YouTube" as the search term. Only 24 were from "education in scientific disciplines," and none of these studied the question of *what* science (content) is learned and *how* it is learned. Similar results are obtained from the articles in the "education/educational research" category. There are 0 results for a search of "YouTube" in science education journals.

screening, or evolution (e.g., Rose, 2003). Nor are we thinking broadly of online science materials as "important tools for combating the widespread scientific illiteracy" (Weigold and Treise, 2004: 229)—as urgent as that may be. Instead, we think about these materials as means to generate and "live again" a first idealization of scientific sense.

2. From common sense to scientific sense: a phenomenological account

2.1 An often stated problem: misconceptions and scientific illiteracy

There are over 8,000 studies that confirm that the world children encounter and understand is a non-scientific one (Duit, 2009). Researchers have documented that what people of all ages say about the heart frequently is inconsistent with scientific explanations. Some studies reveal that children talk about the heart as if it were storing and purifying blood or as if it were functionally subordinate to breathing (Gellert, 1962); others suggest that the heart is responsible for transforming food into blood (Teixeira, 2000). In a Slovak study, many future primary teachers said that the beating of the heart simply prolonged life (Prokop and Fančovičova, 2006). Most of the secondary biology teachers in another study were said to have misconceptions about (a) the blood flow and blood pressure in the capillaries or (b) about the exchange of nutrients and wastes between the blood and body cells (Yip, 1998). Fifteen-year-olds in another study did not exhibit coherent discourses about the circulatory system as a whole, including the heart. Thus, children between the ages of 6 and 9 tend to draw isolated organs and blood vessels, so that the heart and the veins, although both represented, remain unconnected (Cuthbert, 2000; Óskarsdóttir et al., 2011). A cross-age study in the UK also showed that there is little difference in the way that eight-year olds and undergraduate students describe body systems, with only 2% rendering appropriate depictions of the entire system (Reiss and Tunnicliffe, 2001). Interestingly, the heart is one of those internal organs more frequently talked about and drawn in the correct location, a fact that researchers have attributed to its beat, implying that it is more easily sensed than other organs (e.g., kidneys or liver Óskarsdóttir et al., 2011). The research thus shows that people of all ages talk about the motions of the heart and blood in ways that are incorrect from a scientific perspective. If these people were to move from an everyday to a scientific understanding, this would necessarily be on the ground and by means of what they already know—on the basis of their existing, pre-scientific sense. The paradox constituted by the fact that the unscientific or pre-scientific is the base for and means by which something scientific is attained is precisely the phenomenon of interest in the present study.

2.2 The learning paradox

As indicated above, the learning problem or paradox for both adults and children—how to arrive at scientific understanding on the basis of non-scientific knowledge and evidence—is exemplified in the case of the earth as an object for the human subject (Husserl, 1976a). Yet as Husserl shows, the earth *cannot be* an object originally flying around the sun, because for the subject, it is the *ground* in reference to which numerous fundamental experiences come about:

> It is this *universal ground of belief in a world* which all praxis presupposes, not only the praxis of life but also the theoretical praxis of cognition. The being of the world in totality is that which is not first the result of an activity of judgment but which forms the presupposition of all judgment. Consciousness of the world is consciousness in the mode of certainty of belief (Husserl 1973, 30; emphasis in original)

In other words, we come to know things to be in motion or at rest only with respect to the earth as ground, in close connection with a pre-existing certainty of belief. The most appropriate pedagogy would build on this connection, and keep it in a transformed way, rather than trying to eradicate the everyday experience and the sense of the earth that goes with it (Wagenschein, 1988). Both resting and moving occurs against a background experience that in itself is *not* made thematic (e.g., our own bodies and the ground beneath me). Thus, "the earth itself does not move . . . only in relation to it are movement and rest given as having their sense of movement and rest" (Husserl, 1940: 309). Husserl refers to these fundamental experiential certainties as "protodoxa" or "urdoxa," emphasizing that these are the condition for the possibility of all further knowledge and certainty. Thus, all experience "rests at bottom on the simple pregiving *protodoxa [Urdoxa]* of ultimate, simply apprehensible substrates. The natural bodies pregiven in this *doxa* are the ultimate substrates for all subsequent determinations, cognitive determinations as well as those which are axiological or practical" (Husserl 1973: 59). Our grounding on the earth constitutes a horizon of understanding within which the experience of objects at rest and in motion emerges: Only this earth is home, as we cannot ever grow up anywhere else (Wagenschein, 1988). It would be absurd, in looking for a misplaced toy or set of keys, to take into account the earth's rotation (at 1500 Kilometers per hour) or its orbit around the sun (30 Kilometers per second). Instead, the *real* problem is how the earth can become an object for us at all, when it is always already the ground of all of our experiences, particularly of objects and their motion.

2.3 Nacherzeugung, Nachverstehen (Urstiftung, Nachstiftung)

2.3.1 The learning paradox and the passivity of the first constitution

Central to the phenomenological conception of learning is the passive dimension of the first discovery or re-discovery of what is later accepted as a scientific fact. That which emerges and sublates what we currently know—i.e., both overcomes and preserves it—is of necessity unseen and therefore unforeseen. We do not control it, but instead, it can be said to "come upon" us (Roth, 2012). That new understanding arising in the process of *Nachverstehen* initially "dawns *upon*" us. There is, as the introductory quotation states, a level of *passivity* in the reconstitution of sense: "the passivity of that which is initially darkly awakened and emerges with increasing clarity belongs [to] the possible activity of a re-remembering [*Wiedererinnerung*] in which past experiencing is lived through quasi anew and actively" (Husserl, 1976b: 370). Moving from the pre- or unscientific to the scientific is problematic because the learner does not have a preconception of the new ground or a presumption of the change from the pre-/unscientific to the scientific ground. The pre-/unscientific therefore cannot be an object in itself to be discarded because it is constitutive of the ground and horizon of understanding, just as the immobile earth is the substrate for all subsequent determinations (Husserl, 1940; Wagenschein, 1988). Our common sense *always* is the initial foundation of what we can subsequently experience and for any subsequent scientific understanding.

2.3.2 The lifeworld as the ground and possibility

Science is a human achievement that as Husserl states, "historically and for every learner presupposes the existing generally pregiven, intuitive *Lebensumwelt* or everyday environment or world" (Husserl, 1976b: 123). The mundane lifeworld that we inhabit on a daily basis therefore constitutes the foundation of every science. Our everyday experiences and immediate perceptions almost certainly constitute the reason why science education researchers continue to find Aristotelian conceptions of motion among both children and their adult teachers. It also seems to offer tremendous, almost insurmountable resistance to any transition to a Galilean or Newtonian conception of the world. But in a process of *Nachverstehen*, every learner can be said to attain something similar to the discovery which led to the first articulation of the science: from everyday understanding, as ground and resource for new understanding, to the new ground and horizon in keeping with the scientific as such. Because of *Nacherzeugung* and *Nachverstehen*, in other words, the lifeworld itself changes: human culture, modes of experience and common sense in which mutual understanding is grounded shift, as it were, beneath our very feet.

2.4 Nacherzeugung, Nachverstehen *and William Harvey's view of the Heart*

Current learning theories of all brands suggest that learners construct their own understandings. This does not explain the objective nature of what is known, particularly in scientific knowledge. Nor does it explain why the simple, empirical, yet systematic investigations or experiments can be conducted anywhere in the world that yield precisely the same observations. A particularly relevant example of such experiments are those initially conducted by anatomist William Harvey (1578–1657), famous for his discovery of the heart's role in circulation. The illustrations included in Harvey's book *De motu cordis* indicate how to conduct such an experiment. This is an experiment that proves that the blood is moving in the veins from the periphery toward the heart. Harvey offers the means, in other words, for the re-production (*Nacherzeugung*) of his knowledge and for achieving of understanding (*Verstehen*) after (*Nach*) his own. When the actions described are performed (e.g., tying up the arm as for phlebotomy to collect a blood sample), then observations can be made. If a finger is held as in the second drawing (Figure 1), then the observer "will see no influx of blood from above" (Harvey 1889: 68). Together, these words and images constitute a sort of recipe for reactivating one of the origins of modern anatomy and the scientific understanding of the function of the heart in the circulation of blood. In the context of medical science, such a reconstitution is as valid today as it was nearly 500 years ago. The initial achievement of a scientific discovery forces the radical revision or overturning of some aspect of pre-reflective or pre-predicative knowledge of the lifeworld. This aspect of the lifeworld then can be said to gradually become the ground that provides for the validity [*Geltungsboden*] of the scientific achievement. Those willing to engage in re-understanding can do so by ways and means that others have taken before them and that can be taken again, for this very reason, by anyone else to arrive at the apodictic—i.e., clearly demonstrable—evidence that led to the first realization and its re-production [*Wiedererzeugung*] (Husserl, 1976b). The philosopher therefore suggests that *Nacherzeugung* and *Nachverstehen* are the reasons for the objectivity of science, objectivity based on the fact that some observation is independent of the individual subject, location, and time of the *Nacherzeugung*. People of all walks in life can reproduce a scientific understanding by taking the same route taken during the first idealization—making present again the originary activity of idealization and the ideal formation.

««««« Insert Figure 1 about here »»»»»

3. *Nacherzeugung, Nachverstehen*: An example

3.1 Background

In this study, we use an example from the medical field, in part because of the importance of William Harvey to the development of science more generally and because of the potential role of health as a context for developing learner interest in science education more generally (e.g., Dillon, 2012; Roth, 2013; Zeyer, 2012). Anyone wanting to be informed about how the heart and circulatory system works has opportunities to find relevant information online. In fact, the editor of a journal on medical education praises the Khan Academy, a YouTube based system of tutorials, as an important tool for teaching about cancer (O'Donnell, 2012). There is an emerging number of studies investigating or advocating for the communicative impact of YouTube on spreading medical information (e.g., Azer et al., 2012; Frohlich and Zmyslinski, 2012; Jaffar, 2012; Paek, Hove and Jeon, 2013). For the following illustrative analysis, we randomly took one of the items that resulted from an online search for videos using the terms "heart" and "circulatory system." The video turned out to be from a popular science series for children and youth: Bill Nye the Science Guy. It has been suggested that "'Bill Nye-ish type of stuff,' . . . would entice [teenage students] to return to a site" (Weigold and Treise, 2004: 238). Typical comments accompanying the video suggest that viewers of all ages appear to benefit from it—e.g., "Lol this made my day. I've been studying for the exam tomorrow for over 4 hours a day for 3 days. This video made me understand it better, in a kinda fun way. :P" and "lol I'm a college_ student, and I'm still learning from this guy." The *Nacherzeugung* or *Nachverstehen* that this video may make possible differs, however, from Harvey's originary idealizations—and of course also from the circumstances he offers for their reproduction—because the common sense of the early 17th century is different from common sense one today. Figure 2 presents the main part of the transcription of a videotape, including key images, from the Bill Nye series available on YouTube on the heart and circulatory system.[2]

«««« Insert Figure 2 about here »»»»

3.2 Analysis

The video makes available a wide range of resources that offer the possibility of *Nacherzeugung* and *Nachverstehen* and, therefore, a transition from everyday sense to scientific sense. Most importantly, perhaps, as our analysis shows, the video capitalizes on the learning opportunities that come with multimodality (e.g., Kress, 2010; Kress et al., 2001). Though any one particular viewing might be insufficient to produce a complete scientific understanding, the possibility to do so is given with the resources provided.

3.2.1 From commonsense to scientific sense

There are at least two lifeworld experiences to which such a video on the motion of the heart appeals. On the one hand, there is the fundamental experience of being in the world, and knowing our way around the world: persons exerting themselves, losing consciousness in an extreme flight manoeuver, standing in a doctor's office, being auscultated. Second, these fundamental common sense ways of being in the world become the basis of an extension into the scientific view of the heart and its motions in the way that these have been conceived of by Harvey (1628) and his successors.

On the vertically subdivided screen, one part continuing to show the busy exercise room, Bill Nye emerges, as if from exertion on the right, the left part featuring a cross-section of the heart, filled with blue and red liquid. An appeal is made to relate the heart to the exercise in the gym behind Nye, which may evoke in the viewer past experiences of exercise, and to the sound of the beating heart, which is audible together with the noise from the gym. The image (turn 02) is also a representation or, in the discourse of the social studies of science, an *inscription*. It is no longer a naturalistic depiction, such as shown together with the lungs in Descartes (1662) or verbally described by Harvey (1628), but a cross-section that is unavailable to natural observation. It is also a form of presentation that at the time of Harvey was not yet used or known. (Contemporary illustrations typically show

[2] The videotape is available at. http://www.youtube.com/watch?v=GbttJ-5do9M&lc=TL2097SFBrASMlA0cL91_ZjOAXRQOeV0iwAb_a_BwoI; Details and lesson guides are available at http://www.billnye.com/for-kids-teachers/episode-details/ and http://www.billnye.com/episodes/pdf/episodeguide76.pdf.

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figures with incisions, layers of skin and muscle flayed to reveal hidden bones or organs—with minimal schematic simplification).

There is a slight "pumping action" that is visible—a narrowing and widening of the lower part of the animated representation of the heart (turns 02, 10–12). This is evident when the two extreme configurations of the heart in Turn 10 are plotted unto each other. The periodic expansion and contraction is of the kind that Harvey's description in *De motu* appeals to as visual experience: "the heart is erected and rises upward to a point . . . it is everywhere contracted, but more toward the sides, thus, using less magnitude, it appears longer and more collected" (Harvey, 1628: 22). That is, the animated illustration makes an appeal to the same form of visibility that emerged in Harvey's careful, *in vivo* studies of the hearts of different animals, especially in situations where the heart movements were sufficiently slow to make precisely *the* observations that could become the decisive evidence for the associated idealization. The observation is based on and grounded in the everyday experience of the world, against the resting earth as a ground. The motion, in contrast to rest, is itself perceived and perceivable only against an unthematic ground.

Harvey began his investigation not with the intent to overturn the canonical explanation that was reigning at the time. Rather, his goal was to see the motions and characteristics of the heart [*usu cordis*] via his own observations inspection rather than by what he could read in other people's books. An important dimension of the video is that it makes these motions visible for its (generally non-scientific) audience. Harvey found this a "truly difficult" exercise to the point that he felt God alone could understand the meaning of the heart's movements. He initially could not tell systole and diastole apart, and dilations and constrictions were "like a flash of lightening [*quasi trajectore fulgure*]" (Harvey, 1628: 10). The systole appeared to him at one time here, the diastole there, then reversed, varied and confused. As a result, he could not reach a decision about what to conclude on his own and what to believe based on the writings of others. It is in the course of his investigation of cold blooded animals and his observation of the hearts in dying creatures that he came to identify those moments in the heart's motion that are so unproblematically depicted in the Bill Nye video. That is, this "larger-than-life" (turn 01) model *facilitates* making the *crucial* observations that Harvey's original transition to a scientific idealization required.

Harvey makes reference to three significant observations to be made: (a) the heart rises to the apex (where it strikes the chest such that it can be felt); (b) the heart contracts, particularly on the sides, which makes it appear narrower and longer; and (c) the heart feels harder when it moves then when at rest. He adds that in coldblooded animals the heart is lighter in color during the motion phase than during the resting phase. The translator of the 1928 publication comments on these observations in a footnote to the English text. "This is the first of that remarkable series of extraordinarily acute observations on the motion of the heart and blood so simply and clearly reported by Harvey in this book" (p. II.29). These observations can be made in different parts of the excerpt (turn 02, 07, 09) but especially when the cross-section of the heart is shown as it pumps the blood to the pulmonary system and into the body (turns 10–12).

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Central to the perspective Harvey developed was the *fourfold* chambers of the heart and their relative sizes. This number is also made explicit in the video, already apparent at turn 02, but especially from the image and text in Turns 10–12. What Harvey first articulated as the different roles of the two sides of the heart, one in the circuit to the lung and back, the other in the circuit to the periphery of the body and back, is indicated in the video in the different coloring, blue for the left, and red for the right (from viewer).

3.2.2 Visibilization

The motion of the heart is only very indirectly accessible to everyday experience and, therefore, is not subject to the same kind of apodictic evidence that provides us with our everyday, common sense of the world. The blood circuit is also not available to observation as such. It is therefore not surprising that these features, do not generally appear in children's drawings or that even teachers have misconceptions about this bodily system. In fact, the blood circuit was not available to Harvey, in whose time the body was thought more of as a collection of different organs—much in the way that children represent these today. In fact, the translator of the 1928 edition notes that Harvey, in his philosophical orientation, is still fundamentally Aristotelian. One way of describing the issue, therefore, is in terms of a transition made from an Aristotelian perspective (Harvey, 1928, footnote 7: II.44) to what subsequently came to be recognized as the first modern description of the motions of the heart and blood and a first modern explanation of its circulatory function. That is, on the grounds of an Aristotelian worldview, as embodied in the work of Galen, a new, very different worldview arises. It is in and through such representations as presented with Turn 09 and Turns 13–14, that everyday experiences with liquids flowing and under pressure may afford idealizations of the circulatory system. That is, although not visible as such, knowledge of a circulatory *system* is enabled through the use of inscriptions that themselves draw on experiences in our technologized world.

3.2.3 Appeal to everyday, practical understanding

As suggested above, the lifeworld is the intuitively concrete world that is antecedent to science, but which always relates to the former with respect to the constitution of sense. Any scientific object, any scientific discourse, is based on our mundane, everyday common sense, however much the former might seem to contradict the latter (Husserl, 1976b). These understandings are extended metaphorically to the aspects and functions of the body that are not immediately accessible by the senses.

Following the part of the video featuring representations of the heart and circulatory system (turns 02–17), the video appeals precisely to everyday experiences in a scene shot on a lawn involving a narrator and a "subject." The narrator, a young woman, talks about normal heart rates and compares these to rates while sleeping (lower, with diminished need for oxygen), when surprised or scared (when the heart rate speeds up), and while doing "intense physical exercise" (the body needs more oxygen). In the background, a young man sleeps, is suddenly awakened, and then jogs. The video finally shifts back to black and white documentary footage, with a doctor auscultating a baby and then an old man, while explaining that the heart beats about two and one half billion times over an average lifetime. Harvey, too, appeals to the everyday experiences of the pulse and its change with various activities.

> It is not supposed to be that the uses of the pulse and the respiration are the same, because, under the influences of the same causes, such as running, anger, the warm bath, or any other heating thing (as Galen says) they become more frequent and forcible together. . . . but in young persons the pulse is quick, whilst respiration is slow. So it is also in alarm, and amidst care, and under anxiety of mind; sometimes, too, in fevers, the pulse is rapid, but the respiration is slower than usual. (Harvey, 1628: 15 [1928: II.15])

In this paragraph, Harvey appeals to the very same everyday experiences as the analyzed video does. This highlights the specific observations that can be made in such situations: the sound of an accelerated heartbeat is audible after exercising, and illustrated when Nye is moving into and through the gym or the teen is jogging. These, then, become part of the (what shall become the scientific) argument that respiration and blood flow are two separate systems.

Prior to Harvey, a particular, shared sense certainly did exist about the heart and blood in the human being. Shakespeare, for example, writes of “a voice issu[ing] from so empty a heart,” then confirms that the common saying is true “The empty vessel makes the greatest sound.” These types of sense are based on the self-evidently true (apodictic) experiences of people generally and scientists in particular. Harvey’s “discoveries” arose from and against this common sense. But because Harvey himself grew up in this culture, in and through his scientific practice, a new “sense” came to work against and overcame his existing common sense. At the same time, this experience with the tools and materials for his work provided the foundation on which the new scientific sense is to be built. Moreover, the old sense does not completely disappear: it continues to exist in the general culture, as shown in the science education literature reviewed above. Since meaning or “sense,” as Husserl explains, “is grounded in sense, it is valid to conclude that the earlier sense gives something to the later sense, enters it in a way” (Husserl, 1976b: 373).

The video, finally, is characterized by a functional discourse prefigured, but not fully realized, in Harvey’s idealizations. Harvey generally did not write in the functional language that would only develop during the later part of the seventeenth century. In his text, the word *ūsus* [use] and its inflections are much more frequent than the word *fūnctiō* [function].” But his descriptions, by means of *Nacherzeugung/ Nachverstehen*, make it into a part of the general culture and also into other sciences: they not only lend themselves to such developments, but also they became the sources for metaphorical and analogical extensions into other fields, such as economics, where the idea—one might even say the “culture”—of continuous circulation took hold: It is only after Harvey that the category of circulation became a fundamental analytical tool (Foucault, 1966). In fact, it was over a century later that *function* takes on the dominant role over *structure* and other descriptive approaches to organisms.

3.2.4 Appeal to other experiential modes

Besides the visual mode, the video also provides resources for the auditory sense. Throughout the video, there are periods when the audience can hear in the background of the soundtrack, more or less clearly, the beat of a heart (e.g., during the opening part, when Nye shows up on the split screen next to the heart, turn 02). The beating heart, especially following exercise, is something directly accessible to our senses. The pulse, too, is easily accessible; and we learn early in life how to feel the pulse on the neck or near the base of the thumb. It is a common experience that offers opportunities for an idealization of the organ. Harvey uses the analogy with a horse that drinks, whereby the movements of the throat can be heard and felt. A similar case exists in the heart, where with each portion of blood transduced in the veins and arteries, "a pulse is made, and can be heard in the chest [*pulsum fieri, & exaudiri in pectore contingit*]" (1628, p. 30). Leake (Harvey, 1928, p. II.49) notes that Harvey's is one of the first recorded observations of the heart sounds. Today, such as in the video, no special mention is necessary that the pounding we can hear while exercising is associated with the heart.

4. Discussion

In this study, we have used Husserl's phenomenological perspective on the question of the overturning of pre-scientific understandings through common sense and sensuous observation and evidence. The pre-scientific understanding comes to be sedimented in, and to form the basis of, scientific understanding even as the former is overturned. The essence of our proposal runs like this: In every constitution of (scientific) sense that occurs as someone engages with online materials such as a YouTube video on the human body, something of the original constitution and experience of the body is relived and reenacted. However, because culture has changed, the constitution as a starting point is no longer exactly the same: as that which is apodictically self-evident, everyday common sense itself has changed.

Such a phenomenological approach is fruitful, as Husserl articulates a key problem that few—philosophers, educators, and educational researchers alike—pose, let alone consider and attempt to resolve. How does the way in which experience the world everyday—the world that is the world of our concrete, real experience, which in fact gives sense to the word "world"—lead to often abstract *scientific* knowledge, which is sometimes in manifest contradiction to aspects of common experience)? Even more fundamentally, how can mundane, everyday knowledge be used as a resource for achieving a form of knowledge that ultimately transcends and sublates the quotidian? Why try to lead laypersons in effect to abandon knowledge and sense constitution that likely has served them well for decades? (e.g., Wagenschein, 1988) As Husserl (1976b) suggests, in our pre-scientific life experience, we participate in the Heraclitean flux of changing, sensualobjective givens. Although things change, we are certain to see, touch, and hear them, that is, know these things in their properties as objectively real things that are in this and not in another way. This certainty of things, and the associated apodictic certainty that we associate with the everyday world, gives us a sense of objectivity and reality. Our normal, everyday, mundane, and practical lives are characterized by this sense-certainty, to which the video also appeals. We share this sense with others, because of the common experience of a pathic life, which also is the ground of em*pathy* and sym*pathy* (Henry, 2000). It therefore becomes the basis upon which the pedagogical function of the video rests. This everyday, common sense constitutes the ground and horizon for everything else we do and learn. It circumscribes the source of sense on which other, newly acquired sense is built in a continuous expansion and transformation.

Our review of the literature suggests that incomplete and scientifically incorrect concepts and accounts of the human body are prevalent among people of all ages. These descriptions and concepts, to paraphrase Husserl (1976a), are *essentially* rather than *incidentally* inexact; therefore, they are nonscientific. This is so because scientific terms, including force or pressure (e.g., exerted and produced by the heart), denote phenomena that themselves cannot be seen. These phenomena, therefore, cannot serve as *apodictic* evidence and, therefore, already constitute (part of) a transformation to scientific sense. The closed circle of the blood cannot directly be experienced and, in Harvey's work, arose from *inferences* rather than from observation (e.g., compressing veins, generalizing from decelerated function of the dying heart to the normal function of the healthy organ).

In the online video, viewers come to be presented with the image of a two-color circuit. It is a finished result from observations and inferences not thematized in the video. In Harvey's *De motu cordis*, on the other hand, we can clearly observe the descriptions that serve as the basis of inferences. Some of these descriptions were already known to others and, therefore, also part of the Aristotelian viewpoint that was integral to Galen's doctrine about the heart and blood. One of the ideas that Harvey created, in and with *De motu cordis*, was that of a continuous circuit as part of which the heart has a special role: that of pushing the blood into the arteries right to the peripheral vessels. The parts and their names already existed. It was the *function* and the *functional whole* that changed with the work of Harvey. There is empirical evidence that everyday folk today have to move through the same sort of process to achieve a first idealization. Thus, a study that analyzed the differences between experts and novices of complex biological systems, including the human respiratory system showed that whereas there are little differences between the groups on structures, but significant differences existed between them on understanding functions and causal relations (Hmelo-Silver et al., 2007). Similar developments are born out when people are asked to categorize, where shifts have been observed between categorization according to domain towards causal relations across domains (Rottman et al., 2012).

In the video, the heart is presented as a pump. Harvey himself did not explicitly see the heart as a pump operating in a closed system to keep the blood flowing. It was Descartes (1662) who articulated, 20 years after *De motu* was published (i.e., in 1648), the idea of the human heart as a pump, the blood vessels as a circulatory conduit system, and the human body as a machine. The video clip appeals to this common experience in the world, in which learners of all ages experience the function of liquids and gasses being pumped and under pressure in a range of technical contexts (e.g., swimming pools, hospitals, bicycle repair). These everyday experiences change in the course of human cultural history. Thus, what was part of the everyday experience of being in the world at the time of Harvey was different than those into which we are born today. For example, pumps, plumbing and other machine systems are part of the everyday world that constitutes common sense and, therefore, the background against which we constitute the sense of every new experience. These provide resources for understanding the heart and circulatory system as systems, powered and sustained by the systemic operation of machine parts that together form a coherent and interdependent whole.

5. Coda

It has been suggested that scientific breakthrough itself cannot be shown in film (Rosenstone, 2003). We suggest, grounded in the work of Husserl, that viewers of visual online materials can relive an (aspect of an) originary scientific breakthrough such as the originary constitution concerning the motion of the heart and circulatory system by engaging with visual, online media and a lifeworld replete with technical examples of the principles at stake. This approach also throws into relief the talk about information available (Rosenstone, 2003), because the sense-constituting act that gives the person scientific understanding also constitutes a change in perception, the horizon of understanding, and, therefore, in what the nature of information is (Merleau-Ponty, 1964). That is, there is a revolutionary process at work, in which pre-scientific forms of apodictic evidence are both overcome and kept in the new forms of evidence that constitute the new, technologized scientific understanding.

Scholars working on the topic of conceptual change in science often deplore the apparent resistance of students to conceptual change and the cultural continuity of existing conceptions. The phenomenological perspective provides an alternative to this literature. It also extends this literature in that it has an answer to the apparent persistence of non- or pre-scientific discourses. First, all science is grounded in our everyday experiences; and these have not essentially changed in the course of history: We continue to see the sun rise in the morning and to see it set in the evening; and we continue to feel the cold come into the door rather than heat being lost to the outside. Second, the initial worldview and understanding does not disappear with the adoption of a scientific worldview. Rather, the original worldview comes to be sublated in and with the new, that is, it comes to be both overturned and kept alive, sedimented in our understanding as the foundation upon which science is built (Husserl, 1976b). Thus, physicists and astronomers continue to marvel at and enjoy a beautiful sun*rise* or sun*set*, even though at work they would label as naïve or unscientific any person who seriously supposed the sun to be moving (around the earth). The real marvel that we observe daily in the world around us is that people do learn science *and* continue to talk about the everyday world in pre-scientific terms. Once seen in this perspective, it is evident that we do not need to eradicate prior (mis-) conceptions but rather design science education in a way that allows people of all walks of life to hang on to their familiar discourses all the while developing new forms of (scientific) discourse that are useful in special purpose contexts (science classrooms, science careers).

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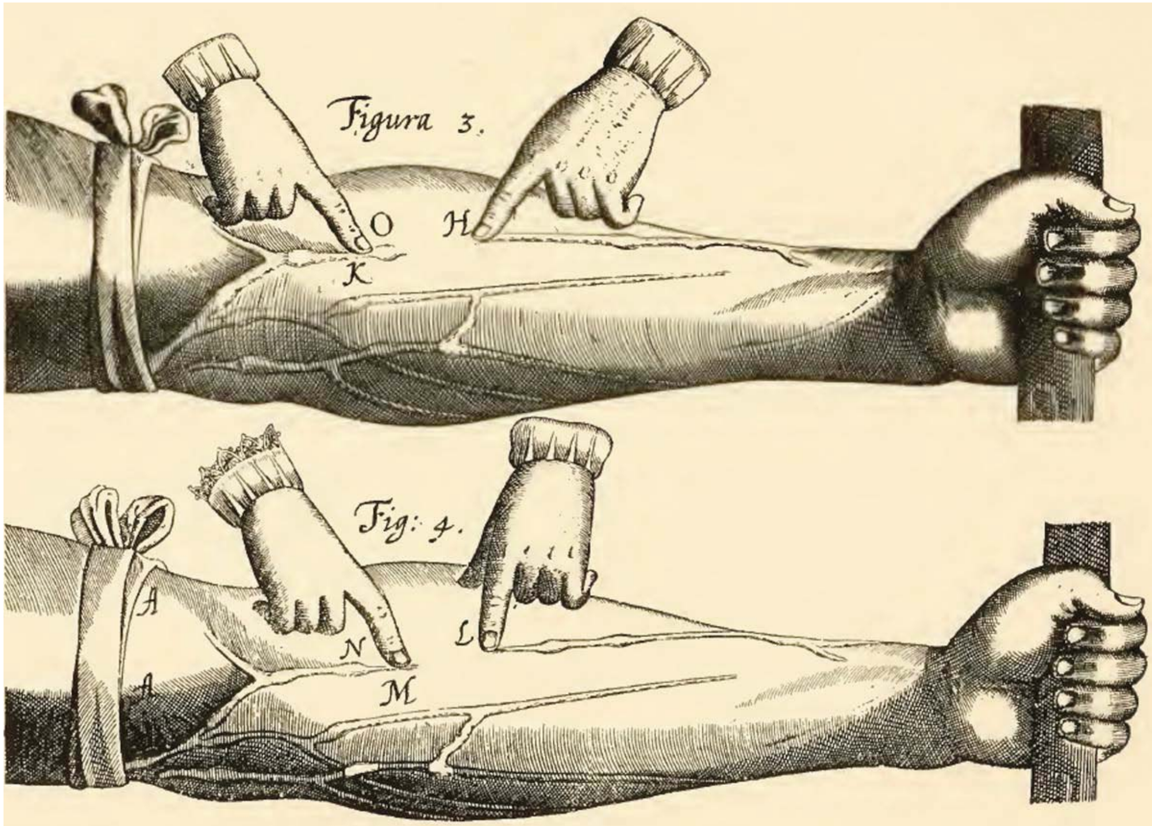
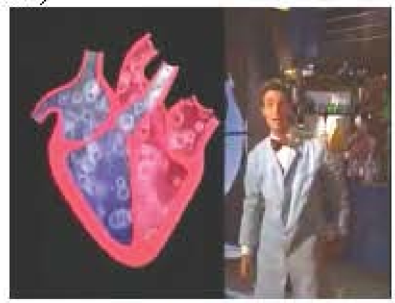


Fig. 1. Harvey's illustration for how to see the presence of valves and direction of blood stream

00 ((*Bill Nye in a fighter jet doing a loop; Nye loses consciousness as the G-forces increase in the maneuver; BN climbing a rope into a gym, with his heart rate shown to increase through the exertion; BN then moves forward, eventually appearing on a split screen, the other half of which is occupied by representation of the hear.*))



01 BN: * It's our larger than life heart model of science.

02 Your heart is a pump.

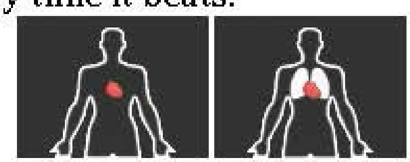
03 VOICE OVER: * It is the pump.

04 BN: It pushes blood all over your body. ((BN portrait shot))

05 VOICE OVER: * It's the heart's job to keep the blood in motion.

((*Return to illustration, turn 02*))

06 BN: ((*BN, portrait shot*)) Your blood carries fuel, energy from your food and oxygen. Plus your blood caries your body's waste away, too. ((*Illustration, turn 01, with movement of blood through upper body.*)) Your heart sends blood in two directions every time it beats. * The blue blood has very little oxygen * and your heart pumps it to your lungs. ((*Blue in "lungs."*))

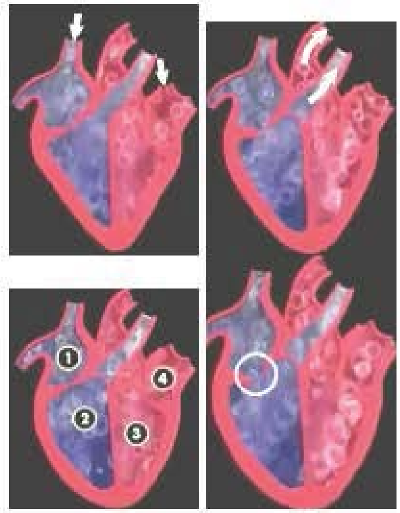


07 where it gets recharged with oxygen. The read ((*red in "lungs"*)) oxygen rich oxygen gets pushed from the lungs back to your heart.

08 And from there it is sent to all the other parts of the body, what we call your system. ((*split screen, as in turn 01*))

09 VOICE OVER: * The heart powers the circulatory system. It is the pump.

10 BN: ⁺ ((*Split screen, with* heart)) To send blood two ways at once... your heart has two sides. And each side has two parts, or chambers, so.



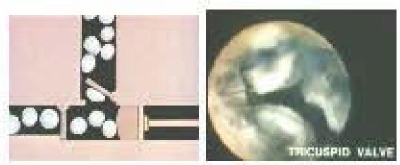
11 ⁺ So all together we got four chambers.

12 ⁺ Now to make that work, your heart has valves, like gates, between the top chambers and the bottom chambers. ((*Different valves highlighted with circle*))

13 Without the valves, this pump wouldn't work. <<p> it's a cycle, your heart pumps blood to your lungs back to your heart.

14 to your system and back to your heart ((Underlying beat)) and it does it all the time and it's only this big ((shows fist)) and you don't have to think about it.

15 ⁺ Valves keep a liquid flowing in one direction. ⁺ ((sequence of 3 valves in action, tricuspid, pulmonary, mitral, and aortic valves))



16 VOICE OVER: ((*Change to excerpt appearing as if from old documentary, voice reads text also seen*)) Warning, what you are about to see is a real human heart. This isn't going to be another rubber prop heart. Nope, this baby is real. A real working pumping human heart, surrounded by lots of blood and guts. If you are faint of heart or get queas- ((*shift in image*)) Parents do you [have] eyes over your hands yet?

17 VOICE OVER ⁺ ((*Documentary voice*)): Take a look. Your heart. ((*Dramatic music*)) ((*The documentary shifts to show an auscultation*))

18 ((*Shift to a scene on the lawn. Teenager sleeping, awoken by noise, jogging on spot; older female provides a description of what heart does.*))