

Humans, intentionality, experience and tools for learning: Some contributions from post-cognitive theories to the use of technology in physics education.

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Abstract. Human cognition cannot be properly understood if we do not take the use of tools into account. The English word cognition stems from the Latin “cognoscere,” meaning “to become acquainted with” or “to come to know.” Following the original Latin meaning we should not only study “what happens in the head” if we want to study cognition. Experientially based perspectives, such as pragmatism, phenomenology, phenomenography, and activity theory, stress that we should study person-world relationships. Technologies actively shape the character of human-world relationships. An emergent understanding in modern cognitive research is the co-evolution of the human brain and human use of tools and the active character of perception. Thus, I argue that we must analyze the role of technologies in physics education in order to realize their full potential as tools for learning, and I will provide selected examples from physics learning environments to support this assertion.

Keywords: Labwork, experience, mediation, pragmatism, phenomenology, philosophy of technology, MBL.

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INTRODUCTION

In 1940 Müller [1] stated that:

“There is little evidence to show that the mind of modern man is superior to that of the ancients. His tools are incomparably better.”

I argue here that to study cognition properly we must take an experiential perspective [2, 3] and study person-world relationships. To do this we must study the tools, i.e. technologies, used by humans since, as implied by Müller above and succinctly expressed by Mitcham [4], we “*think through technology*.”

COGNITION AND MIND

The English word “cognition” stems from the Latin “cognoscere,” meaning “to become acquainted with,” “know” or “to come to know.” Thus, the meanings of the word’s roots indicate that we should not merely consider “what happens in the head” when studying cognition. It is important to understand that “cognitive science” is not synonymous with “cognitivism” or “mentalism.” What he calls the “myth of Descartes” and concepts of mind are more thoroughly discussed by Ryle [5]. Still and Costal [6] have summarized the dogma of cognitivism as

“the presumption that all psychological explanation must be framed in terms of internal mental representation, and processes (or rules) by which these representations are manipulated and transformed.” (p. 2)

Instead I argue, following Dewey [7, 8], Peirce [9] and James [10] that cognition is related to capabilities for action [11, 12] and is itself a specific kind of action of the human body. This is stated by Rorty [13] as: “[we should not] view knowledge as a matter of getting reality right, but as a matter of acquiring habits of action for coping with reality.” Similarly, Noë [14] argues that “perception is not something that happens to us, or in us, [but] something we do” and Wartofsky [15] argues that “[separating] *logos* from *praxis* is impossible” (p. 173).

Central to Dewey’s theory of cognition is his principle of continuity, he states [3] that:

“there is no breach of continuity between operations of inquiry and biological operations and physical operations. ‘Continuity’ ... means that rational operations *grow out of* organic activities, without being identical with that from which they emerge” (p. 26).

Pragmatism provides us with a non-dualistic, non-representational model of an embodied mind. Lakoff and Johnson [16] (cf. [17]) purport the importance of Dewey and Merleau-Ponty [18] for the idea of the embodied mind. Related to this is the importance

Dewey saw in seeing acts as *dynamic* and *holistic* units. In his classic paper about the reflex arc concept [19] he criticized theories that turned the dynamic process of acting into a sequence of static and disjointed stimuli and responses.

In recent findings of cognitive science there is mounting evidence that the human brain co-evolved with the development of human culture and human use of tools [11, 20]. The neuroscientists Quartz and Sejnowski [21] summarize this as follows,

“culture plays a central role in the development [together] with genes to build the brain that underlies who you are” (p. 58). They argue that “the central role of culture in our mental life reveals that intelligence isn’t just inside the head” (p. 233). They further claim that “Our brains evolved to engage the world ... not to sit around passively. ... Brain functions ... are highly integrated and crosscut ... ‘multiple’ intelligences.” (p. 249)

In line with the concept of “intentionality” stemming from Brentano [22] the theories of for example pragmatism, phenomenology [23] and phenomenography [2] emphasize that there is no detached thinking, seeing, learning etc. We always think of something, learning is always related to something etc. The term “Intentionality” implies that we must treat the human-world correlate as a single unity, like it is in the “experiential perspective.”

Nardi and Kaptelinin [24] have attributed the term “postcognitivist” to theories of activity theory, distributed cognition, actor-network theory, and phenomenology, that are critical of the assumptions of “cognitivism.” According to them a “major point of agreement among postcognitivist theories is the vital role of technology in human life [and that these] theories are highly critical of mind-body dualism.” I here claim that pragmatism in the tradition of Dewey is missing in the list of “postcognitive” theories. Also, the term can give the mistaken impression that these theories post-dated “cognitivism.” Instead, the term post should be seen as an expression of the currently increased interest in some “classic” cognitive theories.

MEDIATED ACTION AND PHILOSOPHY OF TECHNOLOGY

Human experience of our world is, as briefly mentioned in the introduction, shaped by physical and symbolic tools (mediating tools). The concept of mediation and mediating tools could be represented diagrammatically as:

Human \Leftrightarrow Mediating tools \Leftrightarrow World

Questions about the role of technology (artifacts) in everyday human experience include: How do technological artifacts affect the existence of humans and their relationship with the world? How do artifacts produce and transform human knowledge? How is

human knowledge incorporated into artifacts? What are the actions of artifacts?

Tools play important roles in Dewey's philosophies of both education and technology [25]. In the socio-cultural theory and in activity-theory, which is rooted in the thinking of Vygotsky, “tool” and “mediation” are key concepts [12, 20, 26]. Miettinen [27] has pointed out the similarities between the thinking of Dewey and Vygotsky regarding tools and mediation.

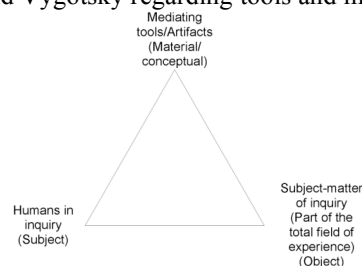


FIGURE 1. A model showing the concept of mediation adapted and modified from Vygotsky [26] and Cole [20]: the triadic relationship between *subject – mediating tools – object* illustrating that the relationship is transformed by mediation.

The philosopher of technology Don Ihde synthesized non-foundational phenomenology and pragmatism in an approach dubbed postphenomenology [28]. According to him perception is co-determined by technology. In science instruments do not merely “mirror reality,” but mutually constitute the reality investigated. The technology used places some aspects of reality in the foreground, others in the background, and makes certain aspects visible that would otherwise be invisible [29]. Neglecting the role of technology in science leads to naïve realism or to naïve idealism [29, 30]. Ihde developed the following schematic distinctions regarding mediated intentional relationships between humans and their world:

Embodiment: (Human \Leftrightarrow Technology) \Leftrightarrow World

Hermeneutic: Human \Leftrightarrow (Technology \Leftrightarrow World)

Alterity: Human \Leftrightarrow Technology (\Leftrightarrow World)

In embodiment relationships we are normally unaware of the technology. In hermeneutic relationships some kind of interpretation is involved, hence the term hermeneutic. In both embodiment and hermeneutic relationships experience is transformed by the mediating technology. In alterity relationships humans are not related to the world through a technology, or to a world-technology complex, but to a technology.

TECHNOLOGY IN LABS

‘Microcomputer Based Laboratory’ (MBL) activities are examples of the use of “interactive technology” as a tool for learning in physics education [31]. In MBL activities students do experiments using various sensors (e.g., force, motion, temperature, light

or sound sensors) connected to a computer via an interface. The arrangement provides a powerful system for *simultaneous* collection, analysis and display of experimental data, sometimes referred to as *real-time* graphing. The PER and lab-based curricula “Tools for scientific thinking” and “Real-Time Physics” have proven effective in fostering a functional understanding of physics [32], and in the “experientially based physics” project MBL has proven to be effective in a Swedish context [33], achieving normalized gains in the FMCE-test of 61%.

However, I have shown that the same sensor-computer-technology (“probeware”) used in MBL can also be implemented in ways that lead to low achievements in conceptual tests, thus refuting technological determinism. My findings indicate that the form of the educational implementation is crucial [33], i.e. we must look at how the intentional *Human-Technology-World* relationship is established.

Nevertheless, as noted by Ihde [29] and Kroes [34], for example, observation is not generally regarded as problematic in positivist approaches and from the anti-positivist perspective, the praxis-ladenness of observations tends to be overlooked. Kroes expresses this as follows:

“[i]n [the traditional] view, the physicist is essentially a passive observer in experiments: once the stage is set he just observes (discovers) what is going to happen.”

Figure 2 illustrates two common views of technology in education. In these views the *Human – World* relationship is not seen as being affected.

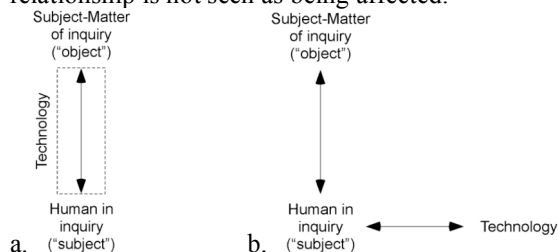


FIGURE 2. a) A ‘Transmissive’ view of technology where technology is seen merely as a vehicle for information b) An ‘Auxiliary’ view where technology is seen merely as a provider of information or support.

According to “Variation theory,” developed by Marton and co-workers [35], we learn through the experience of difference, rather than the recognition of similarity. In this theory the experience of discernment, simultaneity (synchronic and asynchronous) and variation are necessary conditions for learning.

It is not possible in this short paper to present a full phenomenological analysis [23, 36] of the role of technology and the *Human-Technology-World* relationships that the learning environment affords [37]. However, I will briefly discuss an example from one of the earlier tasks in a typical MBL-lab. In this task students are asked to walk a trajectory that matches a

given velocity-time graph. While moving the student, and his/her peers, can see the experimental graph produced in *real-time* (see figure 3). Prior to this, students have solved tasks involving position-time graphs.

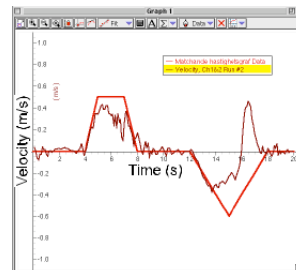


FIGURE 3. Example of a task that students attempt in a MBL-lab. Displayed is a $v(t)$ -graph with a curve that the students are asked to recreate together with an experimental graph produced by a student.

As mentioned above, the way technologies are implemented shapes figure-background relationships, and the variations that can be discerned. Wartofsky [15] expressed this as follows (p. 204):

“I take the artifacts (tools and languages) to be objectifications of human needs and intentions ... already invested with cognitive and affective content.”

What the technology does in this task is to bring velocity to the fore, i.e. it enters in the focal awareness [38] of students. Other features of the situation, physical as well as non-physical, are not highlighted, i.e. some discernment has already occurred. It is also important that velocity is established as a relationship to objects and events in the world (cf. [39]). In order to complete the assignment, students have to understand this and also make important conceptual distinctions.

I have examined labs that use “probeware” and have lead to either low or high achievements. In high-achieving labs the technology is used to bring important concepts and relationships into students’ focal awareness, i.e. it is used as a “cognitive tool.” A preliminary analysis of the critical aspects of “probeware” use have been presented previously [33] and a paper containing an in depth analysis based on variation theory and the philosophy of technology is forthcoming (cf. [40]).

CONCLUDING REMARKS

In this short essay it has only been possible to give a brief account of *some* theories that could be applied in analyzing the role of technologies in physics education. Important theories, such as those for tool-use by Heidegger and actor-network theory by Latour, have not been discussed due to space limitations.

In conclusion I contend that to use technologies as learning tools we must understand their cognitive role(s), identifying which aspects of the world are

brought into focus, thus making learning possible. By understanding this, and the active nature of perception, we can use technologies to their full potential.

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