Living in Mapworld: Academia, Symbolic Abstraction, and the Shift to Online Everything

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Abstract

Paper type: Conceptual

Background: Education research

Approach: Embodiment

Context: During the Covid pandemic, teachers and academics at all levels were abruptly required to learn and deploy generic online educational tools that do not adequately substitute for many classroom or lab practices. In the rush to make education viable during the pandemic, there was little time for critical analysis of the qualities of "online delivery," especially with regard to embodied dimensions of cognition. Conventional academic styles of pedagogy and testing were commonly emulated. In the attempt to simply "keep the train on the rails," there has been little time to assess what – cognitively or pedagogically – has been gained or lost.

Problem: Computer and internet-based interactive applications have specific cognitive affordances and constraints that differ from the tangible embodied scenarios they sometimes purport to emulate. Traditional pedagogy in many disciplines entails a substantial component of "hands-on" learning, a complementary *knowing how* that enables practice, builds skills and provides metaphors and concepts. Existing software and interfaces do not cater well to training embodied skills, and perhaps cannot. In the absence of hands-on lab, studio and clinical experience that usually complements textbook-lecture-test styles of pedagogy, a *knowing that* (as opposed to knowing how) orientation was reinforced. The traditional recognition that embodied experience is an integral component of effective learning has been elided (similar elision occurs with respect to some online research practices). In emphasizing "problem-solving," this instrumentalizing of a knowledge-that style of pedagogy usually elides the syncretic and creative cognitive corollary of problem framing.

Method: I discuss online pedagogy and research from an enactive/embodied critical perspective and juxtapose case examples of embodied practices.

Results: The conclusions drawn from this discussion are that important cognitive differences between face-to-face, hands-on pedagogy and research, and pedagogy and research conducted online are present and critical analysis of the situation is crucial for pedagogical and research effectiveness.

Implications: Whether in pharmacology, mechanical engineering or social media, new technologies and technological systems often have unexpected effects when embedded in society. This is the case with online pedagogy. Critical assessment is overdue. Such will motivate new education research and human–computer design initiatives. Researchers in human-computer interaction, cognitive psychology, education design and other fields should take up the challenge. It remains a possibility that some embodied practices may simply not be compatible with online environments. It is incumbent upon institutions to take such issues seriously, or risk substantial impoverishment of the educational experience.

Constructivist content: I analyze online pedagogy and research from an embodied and enactivist perspective, assessing the different qualities of sensorimotor engagement in screen-based activities as opposed to hands-on experiences. I argue that "knowing" is grounded in sensorimotorically multimodal embodied experiences, and recognize the limitations in the sensorimotor ecologies of online phenomena.

Key words: Content delivery, digital cultures, simulation, multimodality, online interaction, pandemic, pedagogy, performativity, sensorimotor.

Introduction

1. In this article I reflect on the rapid development and adoption of online research and pedagogy, especially through the pandemic. I write this text from the perspective of over forty years of university-level teaching, over thirty years of developing and theorizing digital interactive technologies, and over twenty years of engaging with 4E discourses, particularly as they relate to computing and to the arts, and several years of actively developing class material and teaching in various online environments.[1] As an interdisciplinarian, I am neither a professional philosopher nor a professional education theorist. I am familiar with research into embodied dimensions of learning. It is not my intention here to critique that work, which seems (mostly) laudable. Here, my focus is commercial online educational environments that have been embraced by institutions and that faculty and students have been forced to embrace during the pandemic.

2. I discuss aspects of embodied cognition in pedagogy, research environments, daily life and digital environments and offer conclusions regarding online pedagogy and research. I argue that there are important cognitive differences between actions conducted in the world and in purportedly comparable online simulations of such

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[1] For examples of my theoretical writing and interactive and robotic artworks, see https://www.simonpenny.net

activities – differences that should be considered in the design of online environments for pedagogy and research. That is not to say that interaction with online simulations is not *embodied*, but the standard (phone/tablet/laptop) interface, with narrow channels of input and output (small screen, keyboard, trackpad, limited audio), cannot fully substitute all the complex sensorimotor multimodalities of embodied activities in the lived world. Arts pedagogy serves as a foil in this discussion. The commitment of the arts to hands-on sensorimotor attunement and performativity results in kinds of knowledge practices that are incommensurable with academic symbolic abstraction. Arts pedagogies also emphasize a syncretic "big-picture" problem posing or problem formulation that complements the traditional, often methodologically narrow "problem solving."

Knowledge and academia

3. The Western academic tradition embraces assumptions about the authority of symbolic knowledge that are rooted in Western rationalist traditions. Such a priori assumptions provide the formal foundations of every (academic) discipline, but are themselves not, by definition, amenable to critical analysis. Any purportedly reason-based knowledge system teeters uncomfortably above this epistemological quagmire – logically consistent frameworks are dependent upon assertions that cannot be verified within the logical gamut or frame of that discipline. The system of disciplines we operate within rests on a foundation of what we can only call *beliefs*. This would seem to jeopardize some epistemological or ontological claims.[2]

4. Postcognitivist or "4E" discourses over the last 30 years argue that key aspects of our intellectual systems are premised on non-conscious and bodily kinds of knowing. This conception of knowing is rooted in a holistic, non-dualist conception of cognition epitomized by Humberto Maturana's assertion that "Living systems are cognitive systems, and living as a process is a process of cognition" (Maturana 1980: 13). He elaborated: "This statement is valid for all organisms, with or without a nervous system." This biologically derived conception of cognition meshes with phenomenologically informed notions of pre-reflective awareness, by Hubert Dreyfus, Susan Hurley, Dorothée Legrand, and Maxine Sheets Johnstone (among others) – a kind of bodily knowing that one possesses before one *knows* in a linguistic/conscious sense.[3] George Lakoff and Mark Johnson (1999: 13) argue that 90 percent of cognition is unconscious. If this is the case, the idea of the autonomy of conscious rational thought is destabilized.

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[2] One wonders also about a social structure that enforces this order; it is suspiciously reminiscent of an oppressive priestly hierarchy. From an early age we are indoctrinated with such axioms (they might be the armatures of culture) and woe betide anyone who questions them – dismissive incomprehension would be a typical reaction, but being burned at the stake is not out of the question.

[3] Johnstone was a dancer and choreographer before she moved into philosophy, hence her orientation to such ideas.

5. Whatever our discipline, we academics generate texts: we generate strings of alphanumeric characters that purportedly capture something abstractly general about the world. Academics practice, largely, in what Andrew Pickering (1995) called the "representational idiom," (or at least, we believe we operate in the representational idiom).[4] Whatever the discipline, we *mine the world for symbols*.[5] We build archives and databases, and reprocess abstractions, making *new contributions to knowledge*.

6. There is one group that does not do this exactly. They are the ugly ducklings of (liberal arts) academia: artists. They do not fit the program because, to one extent or another, they do not mine the world for symbols. Constructing empirically verifiable knowing-that via quantifiable findings is not the business of the arts. Rather, artists take "world" and make more world. This is a kind of hands-on engagement with the lived world that often has little recourse to symbolic abstractions of the textual and numerical kinds. It is a *performative* mode that is more akin to gardening than to mining.

7. That is not to say that the performative is not, or has not been, central to many other disciplines. Some academic disciplines are centrally focused on texts, some depend on experiment. Within experimental sciences, the work of a biologist collecting samples in the ocean or maintaining cultures in a lab is grounded in embodied experience, the work of the particle physicist or cosmologist less so. According to the axiomatic privileging of the symbolic over the sensorimotor, hands-on work is often denigrated as *mere* laboratory work or *implementation details*, sometimes delegated to *technicians*. With microelectronics there has been a trend across scientific and medical disciplines to adopt sophisticated instrumentation in place of hands-on measurement and diagnosis: the rapid exploitation of eye tracking in psychology experiments being an interesting case in point. In hospitals, clinical diagnosis: sensorimotorically attuned hands-on discernment of subtle and multimodal cues – feeling a pulse or palpating a belly – is seen as old fashioned, increasingly replaced by sensor-equipped machines with symbolic output.[6] New technologies present us with curious boundary-objects: consider the prosthetic sensorimotor scenario of robotic surgery, where the surgeon manually controls miniature actuators, viewing their actions via miniature video-cameras.

Arts research and pedagogy

8. I take arts pedagogy here as a foil to be counterposed, for the sake of argument, with research and pedagogical styles preoccupied with *delivery* and *instruction*. Arts practices and pedagogies stand apart from the norms of academia. Pedagogy in the arts

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[4] Pickering (1995) deployed the term *performative* in an idiosyncratic way that does not correspond with the way the word was used by Judith Butler (1990) around the same time.

[5] This metaphor, deployed in discussions about information economy, is an elaboration on the concepts of "extraction" and "extractive practices."

[6] The irony here is that in the internet at large, it is people who, by tagging pictures and maps, turn experiences into data for machine-learning algorithms to churn.

is generally inclined to holistic big-picture integration rather than to tunnel-vision specialization.[7] Sculptor Bert Flugelman (personal communication) noted, "Art is not about getting the right answers, it is about asking the right questions." Asking big questions and looking at the big picture is a quality of arts inquiry that is quite different from reductionist and deductive academic modes, and this demands radical interdisciplinarity.

Radical interdisciplinarity

9. The Manhattan project is sometimes cited as an early example of modern "interdisciplinarity" (Karlqvist 1999).[8] However, interdisciplinary amalgams involving say, an engineer, a mathematician and a chemist share assumptions about the nature of research and knowledge.[9] The Macy conferences that birthed cybernetics (1946–1953) were as interdisciplinary as any academic meeting could be, with mathematicians Claude Shannon and Norbert Wiener working alongside neuroscientists Warren McCulloch and Ross Ashby, and anthropologists Gregory Bateson and Margaret Mead (Pias 2004). However, such ontological mixing was pushed past the walls of academia in the arts in the 1960s, where radically interdisciplinary interaction was forged between seemingly incommensurable realms. Such integrative, "big-picture" interdisciplinarity was a countercultural reaction to the idea that better solutions would necessarily arise from increased disciplinary specialization. At the time, such specialization seemed to have failed to resolve mounting global issues – *wicked problems* such as environmental pollution or institutionalized racism. A historical argument can be made that interdisciplinarity, in this radical sense of attempting to reconcile incommensurables was invented in the arts in the 1960s.

Avant-gardism and disruptive thinking

10. The arts, generally, are in the business of *disruptive thinking*, to deploy a term that was briefly fashionable in Silicon Valley a decade or so ago. The arts, at least in the modern period, have a tradition of commitment to experiment and change that makes them temperamentally more inclined to revolution than many disciplines.[10] In the tradition of modernist art avant-gardism, any structuring concept was seen as a boundary to be challenged (the work of John Cage being a paradigm example). The "long" 1960s were a revolutionary period in the arts, where conventional genre, medium

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[7] I am speaking specifically of progressive arts-practice pedagogy of the last sixty or seventy years, not (for instance) of academic art history or music conservatory training. However, arts inquiries also often focus on the experientially specific, and shy away from abstract generalizations, embodying Alfred Jarry's pataphysics, the "science of the particular" (Jarry 1996).

[8] Mitchell Ash (2019) also cites the Manhattan project as an example. For a broad exploration of interdisciplinarity, see Barry and Born (2014).

[9] Ongoing debates about the relative merits of terminology (interdisciplinarity, multidisciplinarity, transdisciplinarity, etc.) notwithstanding.

[10] That is not to say that there are not more, and less, genre-bound and conventional kinds of practices.

or institution-based definitions were simply abandoned. In the plastic arts, the conventional genres of sculpture and painting were suddenly exploded to include (roughly in chronological order) op-art, kinetic sculpture, audio-visual environments, installations, earth-art, happenings, performance art, body-art, video art, and conceptual art. The modus operandi of the period might be paraphrased as – *let us find two or three things that (in our culture) are regarded as immiscible and incommensurable and jam them together and see what happens*. Allan Kaprow's 1966 manifesto *How to Make a Happening*[11] is a paradigm example of that iconoclastic spirit. His first rule states:

> "Forget all the standard art forms. Don't paint pictures, don't make poetry, don't build architecture, don't arrange dances, don't write plays, don't compose music, don't make movies, and above all, don't think you'll get a happening out of putting all these together. This idea is nothing more than what operas always did and you see it today in the far-out types of discotheques with their flashing lights and film projections. *The point is to make something new, something that doesn't even remotely remind you of culture.* You've got to be pretty ruthless about this, wiping out of your plans every echo of this or that story or jazz piece or painting that I can promise you will keep coming up unconsciously." (0:07–0:51; emphasis added)

11. Art practices like this embrace difference and disruption (as opposed to cynical and hubristic box-checking, often seen in corporate and institutional interdisciplinarity). The experimental arts emphasize social and environmental situation, eccentric experimentation and disruptive thinking. In scientific and technical research – in order to make an empirically justifiable claim – variables must be controlled. This necessarily limits ecological validity. In psychology this is called the "white-box" problem, referring to experiments in controlled situations (see discussion below). We might say that arts research sometimes favors ecological validity over empirical validity.

The problem with problems

12. *Problem solving*, that grail of cognitive psychology, has long been a topic of educational theory, addressed from diverse perspectives, cognitivist and constructivist (e.g., Savery & Duffy 1995; Gijselaers 1996). My concern is twofold. First: I emphasize the necessarily prior (or in-parallel development of) problem formulation and *framing* that entails a mode of thinking that is syncretic and integrative as opposed to analytic. Where in academia are techniques of problem formulation explicitly taught? The education of capable (creative, inventive) minds cannot consist solely in the memorization of (what are conventionally referred to as) 'facts', as if every possible problem is already categorized and arrayed on a shelf or in a database. What intellectual skills are required for problem framing? Thinking by metaphor and analogy, inferential thinking, open-ended experimentation, attentiveness to accident, creative conjecture: "what happens if…?" As Nobel Laureate Richard Axel put it,

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[11] "How to Make a Happening" by Allan Kaprow, published in 1966 by Mass Art Inc. on a 12-inch vinyl record.

> "In science, if you know what you are doing, you are not at the cutting edge. So, if you are at the cutting edge, you don't know what you are doing. You don't know what you are going to find. You don't know what the nature of the problem that is sitting in front of you truly is. And you need to develop ways to refine the problem. And that often involves technology. I mean there is a classic feeling among cynics in science that goes: 'That which is doable is not worth doing. And that which is really interesting and worth doing is not doable.' Well the idea is to make the really interesting doable by bringing to those problems the new technologies and the new thinking. And not to be discipline bound. To be able to transcend the different disciplines. And it also makes science fun." (Quoted in Myers & Dumit 2011: 244)

13. While the experimental method emphasizes hypothesis as its first stage, opportunities to develop such skills are rare in risk-averse, failure-averse, modern academia. They appear to be even rarer in online educational environments that reproduce a "problems-at-the-end-of-the-chapter" textbook scenario. To the extent that they replicate conventional *instruction/delivery* pedagogical formats, they strain out problem-framing, generative conjecture, and critical analysis. Thomas Edison is credited for having said, "I have gotten a lot of results! I have found several thousand things that won't work" (quoted in Dyer & Commerford 1910: 616). In order to advance, it seems necessary to comprehend and build upon failures.

14. My second concern with conventional "problem-solving" discourse is that, even when problem posing enters the discussion, it usually occurs within disciplines, for instance, the relatively recent work on problem posing in mathematics pedagogy (Cifarelli & Sevim 2015; Proulx & Maheux 2017) – informed variously by the work of Piaget and Dewey, and enactivist and constructivist thought (Glasersfeld 1991).[12] Interdisciplinary or "wicked" problems that reach beyond the confines of specific disciplines towards socially and culturally situated and performative knowledge-how present a more substantial challenge.

15. One of the values of arts research styles is to counteract the tendency to disciplinary tunnel vision. The idea of "asking the right question" can be reframed as a process of identifying what the problem (that demands solution) *is*. Getting the "right" answer to the "wrong" question is counterproductive, but how do you know it is the "wrong" question? In a toy world the answer can be simple, because the domain is constrained to make it so. In a question like "what should be done about the homelessness crisis?" elucidating the problem itself is much more complex, and "solutions" are different depending on whose interests are being addressed. Designers use the term "wicked problem" for problems with diverse dimensions – take, for instance, a hypothetical wood-processing plant that emits dioxin. It is a scientific and technical (chemical-engineering) problem, certainly, but it is also a social problem (people might lose jobs, investors might lose money) and environmental problem (people and environments are being poisoned), and it is a political problem. Such problems demand the resolution of different interests and criteria that are not just

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[12] Grateful thanks to an anonymous reviewer for drawing my attention to some of this work.

incompatible, but ontologically incommensurable; that is why they are "wicked."[13] It may be that wicked problems are wicked because they cannot be "solved," they can just be ameliorated – we minimize the worst effects and get along with the rest – like Covid. Wicked problems are wicked in comparison to problems of reductionist science that find certainty by constraining the context to a definable logical domain. Heinz von Foerster noted the crucial difference between "hard science" and the humanities as follows,

> "Hard sciences are successful because they deal with the soft problems; soft sciences are struggling because they deal with the hard problems." (Foerster 2003: 191)

Radically individualized pedagogy

16. "Education is not the filling of a pail, it is the lighting of a fire." So, apparently, said W.B. Yeats.[14] Quotations of this kind take issue with the idea of pedagogy as "instruction": that there is a corpus of "facts" that are to be internalized, and the successful internalization of those facts constitutes education (Rylean knowing that). Arts pedagogy proceeds, in my experience, with provision of an array of experiences that provide contexts for students to explore, define and develop their own ways of making sense of, and making their way in, the world. This is a profoundly open-ended process, not unlike the context of scientific research as described by Axel (§12 above). Differences between practices in the arts and practices in academia-at-large lead to tensions regarding concepts fundamental to the formulation of academia – the nature of research, acceptable methodologies, modes of pedagogy.[15]

About "representation"

17. The term *representation* has come to have specialized meanings in different disciplines – from philosophy to mathematics to the arts to robotics to neuroscience to political science – clarification is in order. While some constructivists object to the use of the term representation, in art and graphic-design fields, "representation" is used generically to refer to an image, a picture, a diagram. Additionally, in art history, there is a well-known category of "abstract art" that is counterposed with "representational art." I do not concern myself here with the *mental representation.* Primarily, I draw upon Pickering's (1995) opposition of the representational idiom (the production of symbolic abstractions) with the *performative idiom,* by which he meant, hands-on, sensorimotor *doing things in the world*. This is similar to David Kirsh and Paul Maglio's (1994) distinction between epistemic actions ("physical actions that make

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[13] The term originated, apparently, with management theorist C. West Churchman in 1967, but may have been used previously by design theorist Horst Rittel.

[14] See https://quoteinvestigator.com/2013/03/28/mind-fire/ accessed 5 November 2022

[15] I used to explain this difference to engineering colleagues in the following way: When interviewing a potential graduate student, you say: *you can join my lab and you will help me with my research.* When I, in an arts context, interview a grad student, I say: *you can join our department and I will help you with your research*.

mental computation easier, faster, or more reliable," ibid: 513) and pragmatic actions ("actions whose primary function is to bring the agent closer to his or her physical goal," ibid: 515). It is also closely akin to Ryle's knowing how/knowing that binary. This distinction is captured in my discussion above regarding "mining the world for symbols." It is productive to understand these binaries not in simple opposition, but always enmeshed. For instance, in performative contexts like art production, abstracted artifacts (such as musical scores or design drawings) are deployed, and online screen environments can afford performance.

18. To the extent that images on screens are *pictures*, the term representation is doubly confusing because a representation qua *picture* is static and online representations are dynamic, not simply temporally variable, like a TikTok video, but behaving and interactive. Almost all online phenomena, and the technological armatures that undergird them, are abstractions: code, image files, scripts, databases, lookup tables, authoring environments, markup languages, programming languages, operating systems, protocols: symbols made of symbols made of symbols, *all the way down*, we might say. Indeed, the idea of the separation of symbols from matter is axiomatic in computer science as the hardware/software dualism.

19. All online "interaction" is performative, from playing immersive multiplayer games, to online banking or a Zoom call: from the simple behavior of hyperlinks (that have become second nature, but were, not so long ago, revolutionary), to navigable 3D animations, recommender systems and AI-enabled chatbots (Penny 2009). This paradoxical quality is precisely what demands our ongoing critical attention. Interactive online simulations – *images that behave* – are cognitively novel. In this complicated world of nested abstractions, embodied human users look in from the outside, but reach into, like someone manipulating a net in an aquarium. We can immerse only parts of ourselves; other parts remain sitting in the chair. Virtual reality (VR) and the "metaverse" do not change this, but rather, lure us further into an *uncanny valley* of quasi-immersive manipulable abstractions (Mori 2012).[16] The relationship between that performative surface and the logical depth below is paradoxical. Can a system that is expressed in algorithms transcend logical constraints? Is the cultural frippery of TikTok or Facebook stained and constrained by the abstract symbolic logic of which it is built? Do digital cultural environments inculcate a computational(ist) manner in us? These are specific cases of general questions about the cultural effect(s) of computing as social practice(s), which are seldom asked, less often answered. Online pedagogy and research are cases of such social practices. The following section seeks to address one aspect of this – the automation of abstracted models and simulations.

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[16] The idea of the *uncanny valley* was originated by Masahiro Mori regarding humanoid robots. It suggests, generally, that the more "lifelike" a robot gets, the creepier it is. See also Seberger et al. (2022).

Maps, models and territories

20. Abstractions (equations, diagrams, texts, programs) are simplifications – they leave details out. The problem is how to know what to leave out – judgements of salience. Of all the material dimensions or sensorial experiences, how does one decide what aspects of a situation are salient and which are not?[17] This process of simplification, "sorting the wheat from the chaff," fundamental to the modeling process, can sometimes lead to "tossing the baby out with the bathwater." Hamlet's admonition "There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy" (Shakespeare 1603: 1.5.167–168) should be on the frontispiece of every science textbook as a cautionary warning. Sometimes models are inadequate because of the bluntness of data-gathering or analytical instruments – for instance, the quantity of microplastics in the ocean was underestimated by an order of magnitude because the sieves were too coarse to catch the multitude of smaller particles. This is like proving there is no sand on the beach because you used a kitchen colander. There is also the problem of simply looking in the "wrong place": We only recently discovered that rats giggle when tickled because some bright spark thought to listen at frequencies higher than humans can hear (Ishiyama & Brecht 2016).

21. René Magritte's painting "The Treachery of Images" that has graced the cover of more than one text on semiotics, is inscribed "Ceci n'est pas une pipe." The warning, of course, is that it is a picture before it is a picture of a pipe, and it is not a pipe at all. And what we see is a reproduction of a reproduction of a reproduction – a procession, if not a precession, of simulacra. In the world of online media, we live in a *precession of simulacra* that Jean Baudrillard (1983) presciently foretold, long before internet-web-social technology turbocharged that mediated condition.

Screen-based syllogisms

22. Increasingly, through the pandemic, much of our research and pedagogy, along with social interactions, have moved online. Experimental psychologist Wendy Ross (personal communication) observed that her colleagues increasingly use online experimental environments, for all the obvious reasons: people do not have to come out, they do not have to 'suit up', and it is cheaper. Among this august body of researchers, how many have paused to ponder on Magritte's warning? The assumption that online environments adequately capture all the qualities of the contexts they are supposed to emulate is overdue for examination. For a given experimental scenario, should a mouse- or touchscreen-based experiment be assumed to be experientially equivalent to moving physical tokens on a table? Online experiences and manipulation of physical artifacts are, sensorimotorically, entirely different cognitive domains. To pretend otherwise is epistemological elision. The differences must be articulated. To assert that moving an

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[17] "The answer must entail a sort of practical experimentation extended over time – acting on the system in question, seeing what it does, adapting to that, and so on, in a process I call a dance of agency" (Pickering 2023).

image on a screen with a mouse is equivalent to, say, stacking blocks on a table, is to assert that the differences in the embodied qualities of the two activities is irrelevant. This claim must be justified – it may be applicable in some cases, but not others. To do otherwise would be to assume the map *is* the territory, the perils of which Jorge Luis Borges described in his parable "On exactitude in science" (Borges 1975).

23. It is not just that the interactive graphical world and the physical world have different affordances and constraints. Interactive abstractions of conventional experiments add a second order of abstraction that cannot be assumed to be "transparent." These include semiotically complex "icons" such as: computer interface symbols for "search," "print," "highlight," and so on; graphical symbols such as arrows, flow chart symbols, symbols from formal logic, emoticons ("explosions," fireworks, and so on); graphical conventions such as diagrammatic perspective where diminished size is to be understood as "further away," conventions from animations and video-games such as images of multiple legs indicating running (referencing late C19th time-lapse photography or a "cloud" symbol with vertical lines below, indicating "it fell."[18] Designers of interactive graphic simulations must take great care to capture all that is salient about the lived world, *and* be conscious of unwarranted assumptions concerning the interchangeability of graphical symbols and procedures with bodily experiences.

24. Sensorimotorically, digital interfaces are narrow bandwidth and discrete. This is in contradistinction to non-digital embodied lived experiences, which tend to be wide bandwidth and multimodal. Digital emulations usually fail the test of ecological validity. The limitations of the technology obliterate the complex multimodality of lived world experience by reducing sensory experience to narrow and independent channels of image and sound. Peripheral vision and hearing, proprioception, tactile sensations, olfaction, and their combinations and intersections, are all lost.[19]

Digital cultures

25. There is a lot for us to learn about online interaction, there is a lot for us to learn about embodied, sensorimotor (inter)action, and about the relationships between the two. Per the blurring and combining of performative and representational, we are not disembodied viewpoints when we interact online. Playing esports or poking a phone are embodied activities (Ekdahl 2022). We sensorimotorically interact through digital devices, with software and remote personages, human and synthetic – and in some cases, our houses and our pets. There are transfers of skills, and failures of transfers, between the two. It is complex.

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[18] Also texting subculture abbreviations such as iirc "If I remember correctly," imho "in my humble opinion," afaik "as far as I know," otoh "off the top of my head" (confusingly also "on the other hand"), fwiw "for what it's worth," ymmv "your mileage may vary" (i.e., "your experience may be different") and ttyl "talk to you later." Note that some of these are shorthand for polite caveats, and some are already metaphorical: 'top of head','your mileage might vary'.

[19] Online experiments that relate exclusively to online behavior are on safer ground.

26. We ought to take care to avoid generalizations about "computers" or "computer use." The devices we skeuomorphically call a "phone" or a "computer," are the most sophisticated artifacts humans have made. Technologically, they are heterogenous amalgams of systems – from satellite-based geo-positioning to real-time 3D graphics rendering to touchscreens. Since the early 1990s, all manner of practices that were inseparable from specific technological vehicles have collapsed into digital simulations – photography, literary correspondence, archival research. New digitally native practices have developed and will continue to develop – paradigmatically, multi-user online gaming. Particular "cultures of use" develop, and new tools develop around them – I have no use for auto-completion of Chinese characters in gesture-based touchscreen apps, but millions do. The technological conundrum of the Chinese typewriter has become an anachronism.

27. Usage of such systems influences the cognitive formation of current and future *digital native* generations (Penny 2021). We *adapt* and become naturalized to new behaviors, and we forget.[20] Capability in digital spaces is gained while capability in non-digitally-mediated spaces is lost. Increasingly, (for better or worse) life is mediated by apps and social-media environments: "friends" and "likes" dominate the psyches of adolescents. Aptitude in navigating online spaces and software procedures replaces more grounded kinds of navigational capabilities. This transition is signaled by the shift from the derisive "meatspace"[21] to the implicitly nostalgic "non-digitally-mediated space." We inhabit augmented reality whenever we use our phone.

Embodied experience

Embodied experience with material objects has a capacity for serendipity, accidents and surprise that is often strained out of online simulation.[22] Take, for instance, the "triangle of ten coins" puzzle (Figure 1) typical of "spatial insight problems" in experimental psychology. Encoded graphically on a tablet "The triangle of coins problem is a difficult problem: fewer than 10% solve the problem with their first three moves or solve it quickly" (Vallée-Tourangeau et al. 2021: 4). Would the experimental subjects have been more successful doing the puzzle with physical coins? At issue here is the question of cognitive affordances of different realizations of the problem, specifically the differences between physically manipulated physical tokens and interactive screenal diagrams of the problem. The second is clearly an abstraction that removes certain qualities (mass, texture) that are deemed to be irrelevant in a more cognitivist

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[20] As with measures of environmental change, baseline data is invaluable. Are there relevant databases about peripheral visual acuity or hand-eye coordination among pre-digital children?

[21] "Meatspace" is an old cyberpunk term. According to https://ask.metafilter.com/15851/Origin-of-the-term-meatspace (accessed 30 January 2023), it was first used by John Perry Barlow in 1995. It appears to have been coined in response to "cyberspace" which William Gibson coined in his 1982 novel *Burning Chrome* (1982) and also used in his 1984 novel *Neuromancer*.

[22] Interaction with symbols on a computer screen, tablet or phone is clearly an embodied experience, conducted as it is by a person engaged in sensorimotor behavior with respect to such a device.

understanding of the problem.[23] When played with coins on a table, coins can be dropped, can roll, revealing possibilities. Such possibilities are not coded as *failures*, as they might be in a symbolic context in which (binary) correct and incorrect answers are encoded.[24]

28. Contrary to the 90%, I found the solution immediately. What in my experience made this task trivial for me? I have spent an awful lot of time with very tangible problems of efficiently using available materials, such as making a box of certain dimensions with least cuts and joinery from a pile of miscellaneous bits of wood. Consistent with the arguments of Mark Johnson (1987) and others, I contend that generalizable abstract understandings are derived from such experiences. Contra Kirsh and Maglio (1994), embodied actions are always both pragmatic and epistemic, the ability to separate one from the other is a result of the contrived "white-box" scenario. In mobile animals with at-a-distance sensing capabilities (vision, audition, olfaction), brains developed to coordinate increasingly sophisticated sensorimotor behaviors, including, for humans, wielding weapons and avoiding blows from such. Language, philosophy, mathematical reasoning, and (for instance) playing chess are evolutionarily recent uses for the brain.

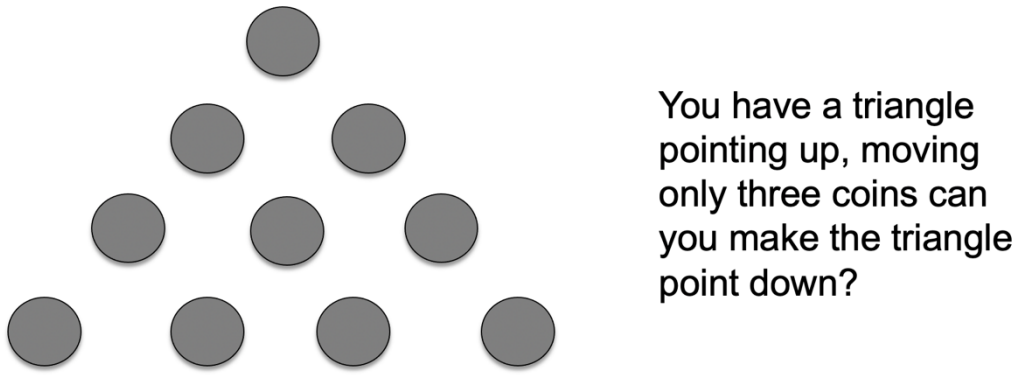

Figure 1: The ten-coin triangle puzzle, sometimes called "inverting the pyramid." Image courtesy Wendy Ross.

29. The synergies of skilled tool use open vistas of new concepts: I cannot deploy a metaphor of warp and weft if I cannot weave. If my immediate insight into the ten-coin puzzle was a result of my hands-on artisanal experiences, then the eradication of embodied hands-on practices such as metal and wood shop in STEM-oriented schools would seem to be misguided. That is not to say that online practices are not themselves sources of concepts and metaphors. As a quick Google search will attest, the internet is awash with protestations that video games may enhance certain kinds of cognitive or

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[23] Little research appears to have been done on this question, though Chronicle, MacGregor & Ormerod (2004) do discuss cases of diagrams on paper as opposed to physical tokens.

[24] Wendy Ross (personal communication) concurs: "failure is often more generative in the physical world because it is not coded as failure."

sensorimotor skills. However, there are also concerns. What if such concepts are inadequate? For instance, naturalization to the false physics of video games may cause an increase in physical injury among children (see discussion of simulator sickness below).

30. I have a minor kind of dyslexia; I have no innate sense of left and right. As a child, I was late to read and write and could not tell the time on a clockface. However, I have excellent 3D visualization skills that I took for granted until it became evident to me that others did not share this capability. I live in a neighborhood where hard, rounded river stones and boulders are plentiful. Some years ago, I laid a path of such stones. I had a pile of stones of varying sizes. I would find a likely contender and fit it into a gap provided by the stones already laid, with a more or less flat face uppermost. Sometimes I had to excavate to accommodate some protrusion, then I would tamp down and move on. I was quietly amusing myself with this three-dimensional puzzle when someone offered to help. After a time, I became aware I had laid 10 stones, they had laid one and were struggling with their second. Reflecting on this later, it occurred to me that my inability to distinguish p from q or b from d, while a significant disability in the world of alphanumeric symbols, was an asset in this world of objects: "b" and "d" are indeed the same character, inverted. This example prompts questions about normative assumptions of alphanumeric literacy in (psychological) experiments, and online simulations in particular. What kind of interactive simulation could adequately simulate the relevant situated and proprioceptive cues that came into play in this playful problem-solving? The narrow-bandwidth I/O channels of the conventional computer preclude sensing of mass, balance, volume or texture in *pictures* of such stones. To take another example, when I shop for avocados, I grip them to assess volume. Complex integration of proprioceptive cues permits me to judge, without reasoning, the largest, even if some are more spherical and some more oblate.

The body in hybrid realities

31. In Penny (1992), I disputed the "embodiment" rhetoric touted by proponents of VR. When I donned the eyephones, I asserted that I "checked my body at the door." In VR, you could not sit on a virtual chair, and if you walked too far, the cable would tear the eyephones off your head, or you would bump into a screen.[25] "Embodiment" in VR has always amounted to a dynamic stereoscopic illusion and maybe a 3D "pointer." VR has always been, proprioceptively, AR (augmented reality), or perhaps MCR (mutually conflicting realities). Not much has changed, it has just got smaller, faster, cheaper and "friendlier."

32. In the early days of "public" VR, people would become nauseous because the image feed could not keep up with the speed of head movement. "VR sickness" continues to be an issue among users and in research contexts (Chang, Kim & Yoo

[25] In those days, VR exhibits and experiments were staffed by minders who were constantly warning users to be careful, sometimes physically restraining them.

2020; Salimi & Ferguson-Pell 2021). In seasickness and other varieties of motion sickness, nausea is a result of a mismatch between the sensory experience of the vestibular canals and the visual field. In flight-training circles, "simulator sickness" has been recognized since the 1950s (Kennedy et al. 1984). Symptoms included dizziness, stumbling, loss of balance and nausea, which persisted after the training sessions. Half a century ago, the US navy was having some issues with pilots crashing planes. It transpired that the pilots who had crashed recently had had sessions in flight simulators (without motion platforms). In a simulator, the screens might show a rolling situation, but the vestibular sense told the pilot they were on the level. The conflict between these sensations was resolved by automatic and unconscious compensation – neurologically "switching off" the messages from the vestibular system. When in the lived world the pilots got into their planes, they could not avail themselves of their vestibular awareness. This is why they crashed. The syndrome became known as *simulator sickness*. (Happily, the cure was simple – a good night's sleep, during which time the vestibular system reconnected). Simulators provide an example of the problems associated with simplifications involved in constructing interactive models.

33. To the extent that online contexts are simulations of lived-world scenarios, when we work online, play screen-based games, etc., something akin to simulator sickness might occur: our sensorimotor capabilities are unconsciously edited, and perhaps our sensorimotor capabilities remain edited when we return to "meatspace."[26] A curtailing of proprioceptive sensitivities can lead to poor balance or stumbling, to clumsy or ham-fisted behavior, and accidents. In overexposed children and infants, there is cause for concern regarding a diverse range of more permanent psychological, neurological, oculomotor and sensorimotor issues from myopia to depression (Penny 2021).[27]

34. Online interaction with narrow-bandwidth input channels and similarly narrow audio-visual feedback precludes subtle multimodalities characterizing skilled bodily practices. Gardening, I proprioceptively integrate various forces as I grip a weed root between my thumb and forefinger, judging the slipperiness or granularity of the soil as I smell its damp sweetness. No one expects a violin to be user-friendly. Successful musicianship involves laborious attunement and refinement of proprioceptive and kinesthetic sensitivities and sensorimotor coordination. The "liberatory" catchphrases of computing, *intuitive* and *user-friendly*, entail a sensorimotor dumbing-down. Of all the sensorimotor capabilities we possess or can develop, computer interaction draws upon a narrow subset. The active visual field is reduced to a narrow angle. Normal visual behavior like tracking moving objects across the full visual field, responding to events

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[26] Some online practices, arguably, do not fit into the category of simulation, such as my current typing into a word processor, even though my keyboard remains skeuomorphically modelled on that of mechanical typewriters of a century ago, and my screen image is still called a "page." Again, when discussing online behavior, we must take care not to impose simplistic binaries between symbolic or abstracted aspects and lived performative aspects.

[27] There is a growing array of experimental and demographic data on this subject, some more conclusive than others (e.g., Liu et al. 2013; Pan et al. 2018; Twenge et al. 2018). See Penny (2021) for further examples.

in peripheral vision, adapting to high brightness or low light conditions, dynamically changing focal distance: all these are bypassed. Unexercised, such capacities have been shown to atrophy or not fully develop in developmental stages. Research into such matters can be expected to be unpopular as it will destabilize more liberatory or optimistic rhetoric of computer and internet corporate interests, and likewise problematize the endorsement of such technologies by universities and school systems.

Pandemic pedagogy, elisions online

35. The pandemic shoved faculty and institutions headlong into online delivery. This rapid pivot was extremely challenging for faculty and for students. It was enormously fortuitous that internet infrastructure and environments (Google Docs, Zoom, Canvas, etc.) were (just) mature enough to prevent the global collapse of higher-level pedagogy. What if Covid had hit in 2010? One can only wonder. A potentially decades-long transition to online mass education happened in two years.

36. The value of online tools, especially during a pandemic, cannot be understated. In the process, administrators and managers have no doubt noted the possibility of increasing enrollment without adding a building. To the extent that it is economically attractive to institutions to maintain the pivot to online, we can assume it will remain a fixture of college life into the future.[28] An issue of equity is looming: online education, being lower cost, will attract lower-income groups to lower-budget institutions, potentially making small group in-person pedagogy the province of the rich.

37. Online teaching environments usually implement conventional pedagogical programs involving texts, lectures, labs, quizzes, and exams (such programs have been critiqued by generations of progressive education theorists). In most (if not all) online pedagogy, abstract symbolic knowledge has received renewed privileging, as a result of the merger of academic *knowing that* (Ryle 1946), with the culture of computing, that paradigmatically assumes, and privileges, abstract symbolic knowledge (computer code). The oft-bandied term *instruction* speaks volumes – as do the internet jargon terms *content delivery* and *content provider*. The new "delivery environment" adds monitoring systems and statistical "bells and whistles" typical of online software.[29] The trend towards the automation of education, clearly evident before the pandemic, has been accelerated by Covid.

38. *Instruction* and *education* are not synonymous. What might have gone "out with the bathwater"? Consideration of the distributed, enactive, embodied and sensorimotor dimensions of the educational experience have been largely elided or ignored in the design of online learning environments. On-screen simulation of laboratory processes,

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[28] My own campus, UCI, is supporting research into mass online teaching, for classes of 1,000–2,000 students.

[29] The current wave of online AI apps (Chat GPT, Vall-E, Lensa, etc.) are adding a new layer of complexity that is beyond the scope of this paper.

technical exercises, clinical practices, cannot substitute for multimodal bodily practices. Ostensibly, simulations of (for instance) laboratory experiments *deliver* the lesson without the time-wasting procedures of working in a lab. The attempt to wash embodiment out of pedagogy assumes that whatever a student learns, in a non-propositional way, from preparing a microscope slide, wiring a circuit board, or machining metal, is irrelevant. Knowing how is regarded as irrelevant in this conception of pedagogy. This would be to deny the value of the dexterity of a surgeon, and more generally, asserts a binary separation of intellect and skill that is untenable from a 4E perspective.

39. Some pedagogies – especially of embodied practices – just do not port online, because the online environment is dedicated exclusively to abstractions. I have not taught a sculpture class in three years. Such deeply embodied pedagogy is inherently incompatible with online delivery. Can you learn to throw a pot from a video? You might learn "about" the task, but you cannot learn, proprioceptively, how to handle a sticky, wobbling semi-rigid mass of mud. Bob Ross could show you what the process of making a painting *looked like*, but nothing in his videos can share the feel of the way a blob of sticky grease held among stiff hairs on the end of a stick interacts with the texture of the canvas.

40. Prominently excised from online instruction is the "art" of in-person teaching. I once quipped to a colleague that lecturing is like doing standup comedy that is not funny. Teaching is a performance – if one is engaged, one is constantly "reading the room": catching quizzical glances or bored expressions, improvising examples and explanations as suits the context. A question mid-lecture can suggest that, for this particular audience, a point requires further elucidation. Most students report that their favorite classes are ones in which the teacher conveys enthusiasm for the material.

Conclusion

41. In this article I have emphasized consequential cognitive differences between face-to-face, hands-on pedagogy and research, and pedagogy and research conducted online. The arguments I have made here begin with acknowledging the privileging of abstract symbolic knowledge in (conventional) academia – an idea that has deep roots in Western rationalist and humanist thought. In counterpoint, I argue that being embodied in the lived world provides the basis for a kind of knowledge that experientially grounds research and pedagogical practices (this is a central argument in the STEAM vs STEM debate, e.g., Abrahamson, Dutton & Bakker 2021; Videla-Reyes & Aguayo 2022). Intelligent action-in-the-world deploys knowledge in skillful performance – exemplified in the arts. Such knowing exists in a realm (knowing how) that is different from that valorized in academia.

42. Embodied experience – abstracted in texts, tables, equations, maps, and diagrams – is instrumentalized as abstract machines we call models and simulations, then reified and automated in computational machinery. Internet culture generally, and online pedagogical environments specifically, are substantially composed of abstractions,

models and simulations, of differing degrees. This world of logically bounded domains (with implicit or explicit assumptions that all relevant factors and variables are already encoded) encourages a "problem-solving" mindset, and precludes the complementary but cognitively entirely different work of "problem framing."

43. Critical analysis of the situation is crucial for pedagogical and research effectiveness. The current challenge is to assess the role of enactive, embodied and situated practices in learning in general (an active research area) and in online environments in particular.[30] A revalorization of embodied, enactive and sensorimotor aspects of pedagogical and research practices will, in turn, generate new design agendas.

44. As the dust settles on the pandemic pivot to online everything, the accelerated transition to online pedagogy and research has revealed new challenges and new questions. We ought to heed the warnings of René Magritte and Jorge Luis Borges, and consider carefully the way such simulation environments are deployed for research and pedagogical ends. In particular, we must be attentive to the embodied, enactive and sensorimotor aspects of conventional pedagogical practices and their absence or distortions in online contexts.

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References

Borges J. L., (1975) A universal history of infamy. Translated by Norman Thomas de Giovanni. Penguin Books, London. Spanish original published in 1946.

Abrahamson D., Dutton E. & Bakker A. (2021) Towards an enactivist mathematics pedagogy. In: Stolz S. A. (ed.) The body, embodiment, and education: An interdisciplinary approach. Routledge, London: 156–182. https://cepa.info/7085

Ash M. G. (2019) Interdisciplinarity in historical perspective. Perspectives on Science 27(4): 619–642.

Barry A. & Born G. (eds.) (2014) Interdisciplinarity: Reconfigurations of the social and natural sciences. Routledge, London.

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[30] Through the 1990s, I built several custom immersive systems for embodied interaction – these all depend on custom hardware and software that attend to enactive modalities beyond the reach of conventional systems. See, for instance, https://simonpenny.net/works/fugitive2.html, https://simonpenny.net/works/traces.html, and https://simonpenny.net/works/petitmal.html

Baudrillard J. (1983) The precession of simulacra. In: Simulacra and simulation. Translated by Paul Foss, Paul Batton and Philip Beitchman. Semiotext(e), New York: 1–81. French original published in 1981.

Butler J. (1990) Gender trouble. Routledge, New York.

Chang E., Kim H. T. & Yoo B. (2020) Virtual reality sickness: A review of causes and measurements. International Journal of Human–Computer Interaction 36(17): 1658–1682. https://doi.org/10.1080/10447318.2020.1778351

Chronicle E. P., MacGregor J. N. & Ormerod T. C. (2004) What makes an insight problem? The roles of heuristics, goal conception, and solution recoding in knowledge-lean problems. Journal of Experimental Psychology: Learning, Memory, and Cognition 30(1): 14–27.

Cifarelli V. V. & Sevim V. (2015) Problem posing as reformulation and sense-making within problem solving. In: Singer F. M., Ellerton N. F. & Cai J. (eds.) Mathematical problem posing: From research to effective practice. Springer, New York NY: 177–194.

Dyer F. & Commerford T. M. (1910) Edison: His life and inventions. Volume 2. Harper & Brothers, New York.

Ekdahl D. (2022) Both physical and virtual: On immediacy in esports. Frontiers in Sports and Active Living 4: 883765. https://doi.org/10.3389/fspor.2022.883765

Foerster H. von (2003) Responsibilities of competence. In: Understanding understanding. Springer-Verlag, New York: 191–197. Originally published in 1972. https://cepa.info/1646

Gijselaers W. H. (1996) Connecting problem-based practices with educational theory. New Directions for Teaching and Learning 1996(68): 13–21.

Glasersfeld E. von (1991) Abstraction, re-presentation, and reflection. In: Steffe L. P. (ed.) Epistemological foundations of mathematical experience. Springer, New York: 45–67. https://cepa.info/1418

Ishiyama S. & Brecht M. (2016) Neural correlates of ticklishness in the rat somatosensory cortex. Science 354(6313): 757–760.

Jarry A. (1996) Exploits and opinions of Dr. Faustroll, Pataphysician: A neo-scientific novel. Exact Change, Boston. French original published in 1911.

Johnson M. (1987) The body in the mind. University of Chicago Press, Chicago.

Karlqvist A. (1999) Going beyond disciplines: The meanings of interdisciplinarity. Policy Sciences 32(4): 379–383.

Kennedy R. S., Dutton B., Ricard G. L. & Frank L. H. (1984) Simulator sickness: A survey of flight simulators for the navy. SAE Transactions 93: 658–666.

Kirsh D. & Maglio P. (1994) On distinguishing epistemic from pragmatic action. Cognitive Science 18(4): 513–549.

Lakoff G. & Johnson M. (1999) Philosophy in the flesh. Basic Books, New York.

Liu J., Esmail F., Li L., Kou Z., Li W., Gao X., Wang Z., Tan C., Zhang Y. & Zhou S., (2013) Decreased frontal lobe function in people with Internet addiction disorder. Neural Regeneration Research 8(34): 3225–3232.

Maturana H. R. (1980) Biology of cognition. In: Maturana H. R. & Varela F. J., Autopoiesis and cognition: The realization of the living. Reidel, Dordrecht. Originally published in 1970. https://cepa.info/535

Mori M. (2012) The uncanny valley (from the field). Translated by Karl F. MacDorman and Norri Kageki. IEEE Robotics & Automation Magazine 19(2): 98–100. Japanese original published in 1970. https://doi.org/10.1109/MRA.2012.2192811

Myers N. & Dumit J. (2011) Haptics: Creativity and the mid-embodiments of experimental life. In: Mascia-Lees F. E. (ed.) A companion to the anthropology of the body and embodiment. Blackwell, London: 239–261.

Pan N., Yang Y., Du X., Qi X., Du G., Zhang Y., Li X. & Zhang Q. (2018) Brain structures associated with internet addiction tendency in adolescent online game players. Frontiers in Psychiatry 9: 67. https://doi.org/10.3389/fpsyt.2018.00067

Penny S. (1992) Virtual reality as the end of the enlightenment project. In: Bender G. & Druckrey T. (eds.) Culture on the brink: The ideologies of technology. Van Nostrand, New York: 231–249.

Penny S. (2009) Desire for virtual space: The technological imaginary in 1990s media art. In: Brezjek T. (ed.) Space and desire anthology. Zürcher Hochschule der Künste (ZHdK), Zurich: 168–181.

Penny S. (2021) Sensorimotor debilities in digital cultures. AI & Society 37(1): 355–366.

Pias C. (ed.) (2004) Cybernetics – Kybernetik: The Macy conferences 1946–1953. Diaphanes, Zurich.

Pickering A. (1995) The mangle of practice: Time, agency, and science. University of Chicago Press, Chicago IL.

Pickering A. (2023) Wicked problems and the cybernetic method. In: Jensen P. & Li Vigni F. (eds.) Critical studies of complexity: Theories, notions, translations and normativity. Editions Matériologiques, Paris. In press.

Proulx J. & Maheux J.-F. (2017) From problem solving to problem posing, and from strategies to laying down a path in solving: Taking Varela's ideas to mathematics education research. Constructivist Foundations 13(1): 160–167. https://constructivist.info/13/1/160

Ryle G. (1946) The concept of mind. Barnes and Noble, New York.

Salimi Z. & Ferguson-Pell M. W. (2021) Motion sickness and sense of presence in a virtual reality environment developed for manual wheelchair users, with three different approaches. PloS One 16(8):E0255898. https://doi.org/10.1371/journal.pone.0255898

Savery J. R. & Duffy T. M. (1995) Problem based learning: An instructional model and its constructivist framework. Educational Technology 35(5): 31–38. https://cepa.info/4713

Seberger J. S., Shklovski I., Swiatek E. & Patil S. (2022) Still creepy after all these years: The normalization of affective discomfort in app use. In: Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems (CHI '22). ACM, New York: Article 159.

Shakespeare W. (1603) The tragedy of Hamlet, Prince of Denmark. Nicholas Ling & John Trundell, London.

Twenge J. M., Joiner T. E., Rogers M. L. & Martin G. N. (2018) Increases in depressive symptoms, suicide-related outcomes, and suicide rates among US adolescents after 2010 and links to increased new media screen time. Clinical Psychological Science 6(1): 3–17.

Vallée-Tourangeau F., Ross W., Ruffatto Rech R. & Vallée-Tourangeau G. (2021) Insight as discovery. Journal of Cognitive Psychology 33(6–7): 718–737.

Videla-Reyes R. & Aguayo C. (2022) Pedagogy of uncertainty: Laying down a path in walking with STEAM. Pacific Journal of Technology Enhanced Learning 4(1): 29–30. https://doi.org/10.24135/pjtel.v4i1.147

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