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Reframing Clinical Workplace Learning Using the Theory of Distributed Cognition

Christoph Pimmer, Norbert Pachler, DPhil, and Urs Genewein, MD, MME

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Mr. Pimmer is an educational researcher, University of Applied Sciences and Arts Northwestern Switzerland FHNW, Basel, Switzerland.
Dr. Pachler is professor of education, Institute of Education, University of London, London, England.
Dr. Genewein is an attending physician and medical education specialist, Emergency Department, University Hospital Basel, Basel, Switzerland.

All correspondence should be addressed to Mr. Pimmer, University of Applied Sciences and Arts Northwestern Switzerland FHNW, Peter Merian-Strasse 86, 4002 Basel, Switzerland; telephone: +41 61 279 18 49; email: christoph.pimmer@fhnw.ch.

Abstract

In medicine, knowledge is both embodied and socially, temporally, spatially, and culturally distributed between actors and their environment. In addition, clinicians increasingly are using technology in their daily work to gain and share knowledge. Despite these characteristics, surprisingly few studies have incorporated the theory of distributed cognition (DCog), which emphasizes how cognition is distributed in a wider system in the form of multimodal representations (e.g. clinical images, speech, gazes, and gestures) between social actors (e.g. doctors and patients) in the physical environment (e.g. with technological instruments and computers). In this article, the authors provide an example of an interaction between medical actors. Using that example, they then introduce the important concepts of the DCog theory, identifying five characteristics of clinical representations--that they are interwoven, co-constructed, redundantly accessed, intersubjectively shared, and substantiated--and discuss their value for learning. By contrasting these DCog perspectives with studies from the field of medical education, the authors argue that researchers should focus future medical education scholarship on the ways in which medical actors use and connect speech, bodily movements (e.g. gestures), and the visual and haptic structures of their own bodies and of artifacts, such as technological instruments and computers, to construct complex, multimodal representations. They also argue that future scholarship should "zoom in" on detailed, moment-by-moment analysis and, at the same time, "zoom out" following the distribution of cognition through an overall system to develop a more integrated view of clinical workplace learning. [end of abstract]

Understanding medical education and practice has extended beyond employing classic behavioral and cognitive stances. Increasingly, such discussions have incorporated socio-cognitive, social, cultural-historical, and situated learning perspectives.[1,2] Similarly, scholars have come to acknowledge that *knowing* is socially, culturally, spatially, and temporally distributed between actors and their environment.[3-9] However, while clinicians intensively use technology[10] and much medical knowledge is embodied, these aspects of knowing tend to be neglected in the medical education literature. Different perceptions of embodiment emphasize, for example, the role of human bodies, local environments, or technical artifacts for information processing[11,12] or how abstract ideas are conceptualized via metaphors grounded in bodily and spatial experiences.[13] In this article, in line with this first perspective, we conceive embodiment as information and knowledge processing in the form of bodily practices and (associated) representations--for example, how medical actors use gestures or gazes to create and share knowledge in their daily work. In the medical education literature, notions of embodiment tend to be neglected and, similarly, only a few theoretical works discuss how knowledge is distributed across clinical systems by mediating, technological artifacts--for example, by means of the actor network theory[14,15], cultural-historical activity theory, or complexity theories.[16,17]

A socio-cognitive theory that addresses and integrates many of these tenets is distributed cognition (DCog). DCog does not limit cognition to the minds of individuals. Instead, it emphasizes how cognition is distributed in a wider system--for example, a clinical department--in the form of multimodal representations (e.g. clinical images, speech, gazes, and gestures) between social actors (e.g. doctors and patients) in the physical environment (e.g. with technological instruments and computers). The collectivist perspectives offered by this theory challenge the predominant, Western medical culture, which historically has promoted individualism, autonomy, and self-help with conventional educational models based on the principles of adult learning theories.[2,18] While others describe the distribution of knowledge (e.g. Cole and Engeström[19]), we build our arguments on the framework by Hutchins and colleagues[20-24], since they make particular reference to process perspectives and to the properties of technical artifacts and acknowledge the importance of gestures and bodily movements, which we consider highly valuable for the clinical context.

In this article, we first provide a typical empirical example of an interaction between medical actors. Using this example, we then introduce the important concepts of the DCog theory. Again using our example, we identify five characteristics of clinical representations and their value for learning. Finally, we discuss the implications of using the DCog theory in medical education for future work. Although this article is conceptual in nature, we use selected empirical examples from our research to support our main arguments. We draw from a number of studies conducted in four hospitals in Switzerland that included participant observation, interviews, and focus groups with the goal of researching communication and the learning of medical students and doctors.

DCog in Clinical Practice: An Empirical Example

See Box 1 for our example of DCog in clinical practice. This example shows how three medical actors--a medical student, a resident, and an attending doctor in the emergency department of a Swiss university hospital--treat a patient who hurt his knee playing soccer. We conducted an informal post hoc interview with the attending involved to gather the in-depth background information. We slightly shortened and modified the case information to preserve anonymity.

Box 1

An Empirical Example of Distributed Cognition in Clinical Practice

First, the medical student questions and examines the patient in the exam room. Then she returns to the computer terminals, where she meets the resident. She briefly presents her findings, then enters them into the computer. A few minutes later, the resident visits the exam room and questions and examines the patient. He wants to exclude a *condylus medialis* fracture so orders a radiological examination. Half an hour later, the radiological images are available in the computer system, and the medical student begins to analyze them. Using a Google image search, she identifies x-rays on the Internet and compares those to the patient's x-ray, using the computer's magnifier function. Finally she asks the resident, who sits next to her: *Can you see anything?*

The resident looks up from the computer screen. He has already analyzed the x-ray. He replies: *No, everything is fine, no fracture. We'll send him home. He should present himself for a check-up to his general practitioner in a few days.*

Then the attending doctor, who oversees all cases in the emergency department, comes to the computer terminal and sits down on a chair behind the student. He points to the radiological image on the screen: *What are we going to do with this knee?*

At this point, the resident gets involved. He turns towards the student and the attending and says: *There is no fracture. I think we should send him home and he should report for a check-up with his general practitioner in a few days.*

The attending turns to the student and asks: *What do you think happened?*

The student responds*: Mhh, I don't know. He hurt himself when he took a penalty.* She points to the spot on her own knee.

The resident involves himself again: *He's got a burning, movement-dependent pain next to the patella.*

The attending turns to the medical student and repeats his question: *Ok, what is our diagnosis?*

The student says nothing; the resident still looks at the two of them. At this point, the attending turns his upper body towards the resident (by rotating his swivel chair) and says: *We need to check the tendon, something could be wrong with it. Here you can see the fluid layer which could explain an injury to the tendon.*

As he talks, he points with his finger to a particular spot on the x-ray displayed on the computer. He continues: *We need to check the tendon here. We need to see if the tendon is torn or fractured.*

As he says this, the attending points to the relevant spot on his own knee and signals with two fingers how the tendon is positioned in relation to the knee. He continues: *If you make a provocation test, stretch it and abduct, then he complains about pain here, right?*

As he says this, he stretches his leg and subsequently turns it to one side (abduction). In the process, he points with his middle finger where he suspects a tendon injury. He continues: *This could be a tear of the* vastus medialis*. In any case, I would carry out an ultrasound examination.*

The ultrasound examination shows that there is indeed a tear, and the patient is presented to the trauma attending on-call.

The DCog Approach

Our example in Box 1 demonstrates important DCog concepts. Like any other cognitive theory, DCog takes its theoretical and analytical basis from the cognitive sciences and attempts to explain cognitive systems. The difference lies in its definition of the boundaries of a cognitive system. Classic cognitive approaches typically analyze how information is mentally processed and represented.[25] In contrast, in DCog, a cognitive system extends beyond the individual's mind. DCog posits that individuals, whenever practical, off-load cognitive effort to technological artifacts in their environment.

In our example, the medical actors processed the patient's information using a computer--for example, the medical student used the computer program's magnifier function to analyze the x-ray. In so doing, the student created a tightly coupled, cognitive system that is itself considered a cognitive element.[20, 22, 23] Its collectivist and systemic orientation makes DCog suitable to explain complex systems and organizations--for example, teamwork in an emergency department like the case in our example. Accordingly, many DCog studies analyze communication and coordination in workplaces. They examine processes that span different situations and, thereby, intend to identify broader, generalizable patterns. The most prominent examples include the analysis of work and collaboration practices in airplane cockpits[23,26], aboard large ships[27], and in engineering[28] and software programming teams.[29]

In addition, DCog explains how cognition in the form of different representations is socially, bodily, and artifactually distributed--in our example, patient-related information is distributed (and thereby transformed) by oral language (speech), gestures (pointing), and written and visual representations in the electronic/physical settings of the computer (documented anamnesis, x-ray) across different actors (patient, doctors, student). Each of these representational media holds different properties that regulate the durability and availability of representations through time and space[23]--for example, unless recorded, doctors' and patients' speech is ephemeral; the patients' bodies and the doctors' memories are more durable; the information presented through the computer (e.g. the x-ray) is, by contrast, relatively stable. The latter also is distributed in the physical space, in that it can be accessed from many computers, not only those in the emergency department.

Using DCog in Clinical and Learning Scenarios

While DCog provides many interesting perspectives and insights, Hutchins and colleagues made few explicit references to its value for education. Other groups from the fields of computer-supported and collaborative learning, for example, have offered more detailed educational accounts of DCog.[30] In linking cognition with culture, Hutchins and colleagues viewed the (cultural) environment as a "reservoir of resources for learning, problem solving, and reasoning". They considered culture as a process that “accumulates partial solutions to frequently encountered problems”[20] and that prevents people from reinventing solutions from scratch. These tenets illustrate how DCog explains learning--as the effective performance of complex systems. From Hutchins and colleagues’ analysis, we know, for example, what sort of wider cognitive processes and interactions are needed to maneuver an aircraft. Accordingly, in most of the publications on DCog, understanding learning is implicitly based on interactional and intersubjective epistemologies--learning is not only based on participants’ interactions, but the interactions themselves constitute learning.[31]

In the DCog literature, much less has been said about learning from participatory epistemologies[32]--for example, how inexperienced pilots develop competence and become full members of the professional community. For an exception, see Seifert and Hutchins.[27] Since a (clinical) system constantly loses “relatively expert personnel” [27] while adding relatively inexpert personnel, we deem the participatory perspective to be highly valuable. In the following sections, we combine interactional, intersubjective, and participatory views. Using our example, we delineate five characteristics of representations and their meaning for the learning of less experienced members of a clinical community.

Interwoven representations

We have already discussed that, in our example, cognition is distributed in the form of verbal (oral and written), gestural, and visual representations. However, each representation alone provides limited meaning. We argue that, for less experienced members of a community specifically, meaning making and learning result from the interplay and interconnectedness of different, multimodal representations (i.e. representations that use different modes, such as speech, writing, images, gestures, body language, haptics, and their interplay). In our example, as the fluid (a dark spot--visual mode) was hardly visible, the x-ray alone provided very limited indication of the possible injury to the tendon, specifically when the resident and medical student viewed it. This information was orally amended by the attending, who, due to his experience, was able to draw from a richer repertoire both of multiple mental knowledge representations and of extensive case knowledge.[33] For the attending, however, verbally describing the exact spot and form of the fluid would have been very cumbersome. His gesture, which provides little information in isolation, also linked his speech with the visual structures of the representation on the x-ray.

Prioritizing one representation over another would ignore both the complexity of the integrated and interwoven performance and the mutual relationship of the different modes. Goodwin calls such combinations of representations symbiotic and environmentally coupled gestures since they mutually construct a whole that has much greater value and richness than its individual parts.[34] Moreover, we also learn from our example how doctors use gestures to connect oral language with their own bodies--for instance, the attending uses his hand to couple oral language (he explains what procedure needed to be applied) with visual and haptic representations and movements of his own knee. In so doing, he added a third dimension[35] to the interaction and a complementary view of the two-dimensional x-ray representation. Our example shows how doctors integrate different linguistic, gestural/haptic, and visual modes sequentially as well as synchronously for truly interwoven and multimodal representations.[36,37]

Co-constructed representations

Close examination of our example suggests that knowledge was not exclusively transmitted from the more experienced actor to the less experienced one. Instead, the participants co-constructed the different representations in a highly interactive, cohesive, and self-referential format and, in so doing, created participatory frameworks for learning.[34] For instance, the attending framed the learning context through the orientation of his body. At the beginning of the interaction, his body faced only the student. By turning his body sideways as he repeated his question to the resident, he included him in the participatory framework. The cohesive nature of constructing representations became obvious when the attending pointed to the spot on his own knee with his fingers. In so doing, he referred to the prior movement of the student, in which she demonstrated where exactly the patient felt pain. This movement is far more than a gesture recipient's response to signal acknowledgement and to display attentiveness; it also shows gesture cohesion across turns of the conversations[35] and represents a gesture "uptake" in the sense of collaborative knowledge construction[31]--a participant (the attending) took up (imitated) the previous contribution (the gesture) of another participant (the student), and he constructed another representation in that he extended his knee and demonstrated a provocation test. These actions exemplify how cognition and meaning are constructed and co-constructed by medical experts and novices together and in a self-referential format.

Redundant access to representations

From a process perspective, in the observed clinical environment, career stage (from student to senior doctor) tends to determine the access and path of information through the system, similar to the flow of information needed to navigate a ship[27]. In our example, the patient was first examined by the medical student, then by the resident, and finally by the experienced attending. This progression and overlap produce high levels of redundancy in the system, redundancy that includes the participants' access to the relevant representations as well as their mental processing, i.e. their analysis and interpretation of these representations. For example, all three medical actors accessed the same information individually by viewing and interpreting the radiological image (though they reached different interpretations). According to the literature, redundancy is useful in detecting errors and promoting a robust complex system[27,38], thereby it impacts the quality of the system overall. In our example, without the attending's perspective, even though he was the third medical actor to analyze the case, the less experienced medical actors would have reached an incomplete understanding of the case, leading to potentially negative consequences for the patient.

Moreover, redundancy is also a crucial aspect of learning for medical novices. Like in our example, redundancy in the exploration and interpretation of patient information allows newer members of a community to develop independently and in a self-directed manner their own mental and embodied conceptions--for example, by examining patients or using an Internet search--and, at a later point, to contrast them with those of experienced doctors. These conditions have been deemed valuable for learning.[39] As in our example, doctors have indicated in the literature that they learn particularly well from near miss incidents, in situations where their developed conceptions might have led to mistakes had it not been for the oversight or consultation of a more experienced doctor.[39] Moreover, we would argue that redundancy allowing students to assume the role of a doctor in front of patients, prior to an examination by a doctor, also gives them a strong sense not only of belonging in the workplace but also of being a central member of a professional community.[32]

Intersubjective understanding of representations

Broadly speaking, intersubjectivity includes a (partially) shared understanding as well as divergences of meaning. Hutchins and colleagues describe intersubjectivity primarily with respect to efficient communication between the pilots in a cockpit.[23,24,26] In operating an airplane, pilots, as equal members of a community of practice, are able to build on their shared knowledge and understanding and to develop shared expectations, expectations about how things need to be done without making them explicit to each other. For example, upon a request from the air traffic control system (an oral representation), the first officer responds to the captain, who posed his question only in the form of a glance. Hutchins and Klausen[23] argue that intersubjectivity is closely tied to the smooth and successful operation of the aircraft and is an important factor in determining the trajectory of information in the system and the properties of the larger cognitive system.

Clinical environments are different from cockpits in that they are less tightly structured and are characterized by much higher levels of intra- and interdisciplinary cooperation.[40,41] For example, clinical environments include nurses as well as students, residents, and doctors from different specialties. These professionals hold diverse levels of knowledge and draw on multiple linguistic and cultural resources. These characteristics may challenge the development of intersubjective understanding between members of clinical teams and may lead to ambiguity, misunderstandings, and breakdowns in which actors are not achieving expected effectiveness[42] with respect to the selection of a retractor in the operating room, for example.[43]

However, while divergence and breakdowns might, in view of a system's short-term performance, be negatively perceived, they can offer rich educational opportunities. The disruption of expectations (or, using DCog terms, violated expectations) with respect to the functioning of a system may help learners to “adopt a more reflective or deliberative stance toward ongoing activity.”[44] In our example, the breakdown occurred when the student is unable to articulate her diagnosis. This breakdown is provoked by the “problematizing moves” of the attending, when he repeatedly asks about the diagnosis, thereby calling “something previously held into doubt.”[45] In our example, as in others[42], breakdowns and intersubjective divergences serve as important stimuli for learning, given that the learners are able to understand the underlying reasons for the breakdown and that the experts made their understanding explicit to the learners.

Substantiated representations

Hutchins and colleagues stress the importance of representations for the smooth functioning of a system, such as an aircraft. They describe, for instance, how in an aircraft speed bugs are set and used as technical artifacts to organize and ease the system's performance in a later landing maneuver. They argue that, by relieving scarce cognitive resources, speed bugs do not help pilots to remember speed but rather help the *cognitive system* to remember its speed.[26] In clinical systems, many technical artifacts are, similar to cockpit instruments, orientated towards the efficient flow of information through the system with the goal of enabling the efficient treatment of patients.[10] In our example, the representations (e.g., the x-ray) successfully acted as mediators of collaborative work in that they supported the treatment of the patient, who was successfully referred to a specialist.

Many technical artifacts are, however, not suited to distribute and substantiate ephemeral representations over time, thereby, to allow for learning that is based on documentation, subsequent reflection, and the sharing of external representations (and associated individual and collective learning experiences). For example, what if the resident and the student in our example wanted to individually reflect on or share their experiences with other colleagues who were not present at the time? Consider this statement from an emergency department doctor who points to the difficulties of sharing a representation, such as an x-ray, which he deemed highly relevant to the learning of less experienced colleagues:

> This morning we had a great picture (x-ray) of a hand, very fine, and not at all easy to see what there was. Of course, when the patient is no longer in the system, I won't go to search again…I showed the picture to those who were there.
> But I have to say that if I had had it saved I'd have shown it to the newcomers as well and would have said: "Have a look, here."

Above, we characterized speech, gazes, or gestures as ephemeral. In this example, we can see that representations in electronic, clinical information systems also can be relatively transient. After the patient was moved from the emergency department to another station, he disappeared from the computer system. To facilitate the learning of clinical actors (and the system), technical artifacts are needed that turn rather ephemeral representations into persistent ones, which can support reflection and interpretation[31] and enable distributed members of a community to reinterpret, reflect, and act on and to better develop shared understandings over time. For this purpose, we may develop tools that permit the multimedia-documentation and individual and social bookmarking of case representations.

Implications for Future Work

By contrasting DCog perspectives with studies from the field of medical education, we suggest that, in the future, researchers should focus medical education scholarship on gestures, haptic practices and other bodily movements, technological artifacts, and the integration of micro and macro perspectives. In the following sections, we elaborate on these three ideas.

Bodily movements as mediators of knowledge

First, we encourage future work to explore in-depth bodily movements, such as gestures, both as part of interwoven representations and as they pertain to learning. They can act not only as peripheral but also as central modes of communication and can serve as rich sources for the learning of clinical actors. While we concentrated on gestures in this article, we recommend that future work also include other representations, such as those created by posture, body position, visual orientation/gaze, eye movement, facial expression, gait, haptics, etc.[37] While Heath and colleagues[46] focus on the potential of video for researching clinical practice, they also provide an interesting example from the operating room, in which an expert surgeon connects gazes, oral language, and gestures to construct complex representations in the form of "interactional accomplishments" to teach her assistants. Koschmann & LeBaron[35] discuss how gazes contribute to and direct the interactions of medical students in a problem based learning environment, and Bezemer and colleagues[47] show how upper body/trunk positioning and movement serve as an organizing feature for social interaction in the operation room. However, despite some studies from the field of surgery, this topic remains rather underexplored in medical education. Recently, Kress[48] rightly noted that, in the medical profession, much knowledge is embodied; he, therefore, advocated an immediate need to develop theories that better explain notions of embodiment.

Technological artifacts as facilitators of clinical practice and learning

To date, "technology-enhanced" learning has been researched extensively in rather formal contexts--for example, how learning materials or activities contribute to postgraduate and continuing medical education.[49-51] Although clinical workplaces are characterized by the extensive use of technological artifacts, much less is known about the affordances of day-to-day technological artifacts, such as surgical instruments, whiteboards, computer terminals, phones, cameras, and other computers. Affordances are, broadly speaking, the perceived qualities of objects/artifacts.[52] One of the few to explore such research, Bleakley[16] discusses the meaning of instruments, such as scalpels, as carriers of cultural wisdom for the medical profession. Robin and colleagues[53] claim that medical educators should take advantage of the disruptive effects of new technologies, such as digital cameras, camcorders, and mobile devices, which allow medical students to access and create digital information. Another topic that should be explored further in the future is the use by clinical professionals of mobile medical apps for practice and competence development in informal settings.[54,55]

Therefore, we argue that future research should analyze and theorize both more in depth and across the breadth of the affordances of the technological artifacts used day-to-day for clinical learning, not as single, isolated devices but as part of the interwoven "performance" of clinical practice.

Zooming in and out: merging micro and macro perspectives

To understand the effects of different representations for learning, researchers must study the subtle details on a moment-by-moment basis. Otherwise, many of the relevant details will not be captured. In this sense, Koschmann and colleagues[45] argue that understanding learning means analyzing "doing learning". While many studies in medical education rely on interview data, studying "doing learning" requires observational techniques and video analysis, which produce richer and more nuanced data.[43,46]

At the same time, researchers should pay attention to how these micro-patterns relate to wider organizational or societal changes. In our example, we showed how the ephemeral representations in the clinical information system impeded learning in a clinical organization characterized by (increasingly) physically and temporally distributed team members. Bezemer and colleagues[43] connect their in-depth analysis of the formulation of requests in a surgical team to the changing, wider social and economic context--they discuss, among other topics, how the high rate of fluctuation and turnover of clinical personnel and cultural diversity result in disambiguity and in "far fewer opportunities to develop a shared language and pass on essential knowledge and expertise to new employees."[43] To merge these macro- and micro-perspectives, Evan and colleagues[56] use the metaphor of a dynamic internet map--they emphasize the importance of "zooming in and out" to develop an integrated view of (clinical) workplace learning.

Practical Implications for Learning and Teaching

In addition to the conceptual and theoretical value of the DCog theory, it also offers concrete support for analyzing and improving education and day-to-day learning, teaching, and work practice. First, as we showed with our example, DCog may help medical students and clinicians understand that medical practice, in particular decision-making, is made up of dynamic and complex processes rather than by individual diagnoses. Accordingly, socio-cognitive theories such as DCog should be integrated into the medical education curricula. For example, medical students may use the five DCog principles we outlined here to analyze and reflect on their clinical experiences together with their clinical mentors and facilitators. In so doing, they may better understand why a clinical system helped or impeded their learning. In addition, doctors and clinical teachers could be encouraged to create and connect rich multimodal representations more deliberately, beyond verbal modes, to improve the understanding of less experienced actors.

Next, as DCog is focused on the analysis of wider (social) systems, the theory could be integrated into team meetings--for example, by discussing how the DCog principles play out in departmental practice and how the distribution of knowledge is facilitated or hindered. Educators also could use short formal educational interventions and team self-review in the form of briefing and debriefing to enhance students' situational awareness.[57] Also, promoting an understanding of clinical practice that moves beyond individual and autonomous perspectives is all the more important in view of medical errors--the contemporary literature suggests that medical errors should be understood as a result of collective practice and of distributed cognitive systems rather than as individual failures.[58,59] More generally, while many of today's clinical change initiatives are driven by commercial imperatives and efficiency considerations, such as shortening the length of stay and length of treatment for patients[60,61], DCog principles may help clinical managers and designers of clinical information systems to better understand how the transformation of processes, technical systems, and organizational constellations may interfere with clinical and educational practice--for example, in situations where management is reducing redundancy or when information systems are implemented that offer limited opportunities for substantiating work and learning experiences.

In Conclusion

In this article, we added to two debates. By discussing how interwoven, co-constructed, redundantly accessed, intersubjectively shared and substantiated representations can contribute to learning and meaning making, we aimed to advance the educational discourses regarding DCog. More importantly, we attempted to make a contribution to the field of medical education by using the DCog theory to identify underexplored perspectives regarding clinical workplace learning. We suggest that, to understand learning and working in clinical contexts more comprehensively, researchers should pay more attention to the ways in which medical and clinical actors use and connect speech and bodily movements (e.g., of the hands, arms, or trunks) with the visual and haptic structures of their own bodies or of artifacts (e.g., technological instruments and computational devices) to construct complex**,** multimodal representations. In doing so, future analysis needs to connect micro and macro perspectives--for example, "zooming in" on detailed, moment-by-moment analysis and, at the same time, "zooming out" following the distribution of cognition through an overall system to develop a more integrated view of clinical workplace learning.

We based our discussion of the use of DCog for clinical workplace learning on a particular theoretical strand and on selected empirical extracts, thus our discussion was non-exhaustive. For example, while we did not do so, emotions also can be viewed through ecological and socially distributed frameworks.[62] In other areas of social research, some of these themes have been discussed more extensively--Jewitt[63] and Kress[64] discussed multimodality and Goodwin[12,34] gestures/haptic practices. Researchers should take these works into account in future analyses.

Still, we deem DCog to be a suitable starting point for future research since it integrates many of these perspectives that have been widely ignored in medical education until now.

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