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Representational Practices and Disciplinary Learning

AFFECT, IDENTITY, AND REPRESENTATION

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Introduction

Representation is a process: a cultural and semiotic practice in which we make, encounter, and use relatively durable signs to help us make meaning across time and events.

Representation is, in significant part, a human bodily activity and the use of representations is thus necessarily also something felt: felt in the sensory sense, felt in the motor sense, and felt in the affective sense. In doing or learning science -- whether talking, drawing, comparing, or communicating -- we feel ourselves enmeshed in processes that engage our bodies in interactions with people and things, and we call some aspects of these processes representation.

How does it *feel* to be engaged in representation? In particular, how do we come to feel differently about different kinds of representational practices, media, conventions, technologies, genres, and forms?

We have come to understand for some time now that learning to practice an intellectual or professional discipline is in significant part developing the specialized *habitus* (Bourdieu xxx) or dispositions for practice, that come to constitute an aspect of our identities as people and as practitioners of the discipline. Identities are always about identification and dis-identification, and these processes in turn are matters of *feeling and evaluation*: what we like and dislike, what we feel comfortable with or proficient at, what feels 'right' to us, and what feels like the kind of thing *we* do and contributes in some way to making us who we are.

Some people love using numbers or mathematical symbols; others feel profoundly uncomfortable doing so. The consequences of these feelings about a mode of representation for learning in science and other areas are well known. Some people love using computers, almost regardless of the interactive genre on the screen, and we can hardly doubt that this has something to do with their identities. Other people feel a strong preference for video over text as a means of communicating or learning, and still others love to draw and use diagrams, which their peers may dispense with or even regard as unsophisticated. Whole cultures, and within them subcultures associated with a gender, social class, or

ethnic tradition, may promote or inhibit particular modes or styles of representation. And they do so largely by inculcating polarities of affect, good and bad feelings, about kinds of representations and representational practices.

What do we know about how professional scientists in different disciplines feel about different kinds of representations? Historically, for instance, we do know that there have been heated professional debates, and rises and falls of professional status, for various kinds of representations (the most famous perhaps being that between the so-called algebraists vs. geometrists in mathematics and early science in the 18th and early 19th centuries; Cajori xxx). We know that mathematical representation has been considered superior to linguistic argumentation and to diagrammatic exegesis in many fields of science, and that such preferences are as much matters of historically specific cultural styles, professional identities and ideologies, and how people feel about using these modes of representation as about any demonstrable necessity.

Visual modes of reasoning have been identified as sources of major insights in science (e.g. by Kekule, Einstein, duToit) and the use of scientific data visualization tools is an important contributor to professional productivity today in many fields. How individual scientists feel about modes of representation plays an important role in their work and the advancement of the field. Since scientific insight into new problems is most certainly a form of learning, it is not just our feeling for the phenomenon, but also our feeling for how the phenomenon is represented that matters to what and how well we learn.

Of course, in a somewhat more sophisticated sense, phenomena and representations are not entirely separable. We engage with phenomena through integrations of multiple modes of representation; even the manipulation of laboratory apparatus is a complex integration of motor practices and genres of apparatus that may both be considered as semiotic texts, even apart from the uses of language and visualization that may be guiding how we elaborate our action sequences over time. It is a truism that all activity is semiotically mediated, if we understand the nature of mediation in its full generality.

Likewise, all activity, all engagement in a wider system, which we may externalize as the 'environment' or objectify as the 'phenomenon' is actively *felt*. We learn by living, by moving, by doing, and none of that happens without being felt. We should get used to saying that *we learn by feeling*, not in some vague and generalized way, but in the sense in which even the feeling of being alive here and now is a highly specific, indeed moment-to-moment-unique feeling. So also the feelings of doing an algebraic calculation, drawing a graph, observing a tiger, or writing a text, are each very specific feelings. We often consider only the discursive aspects of these feelings, those we call their 'meanings', to be relevant to what and how we learn. But that assumption relegates the domain of meaning to a fantasy world of the immaterial, and brackets off learning from action, movement, and the very essence of what it is to be alive.

Specificity of feeling is the common denominator of action and meaning, and it may well also serve to help bridge across experiences in different places, times,

and activities, as we seek, in the moment or retrospectively, to make meaning along the trajectories of our lives, including our lives as scientific actors or actors in other domains where specialized representations are key tools and mediators.

Feeling in the production of representations

Let's first consider the feelings we have as we produce representations, focusing particularly now on those which are most commonly used in the doing and teaching of science.

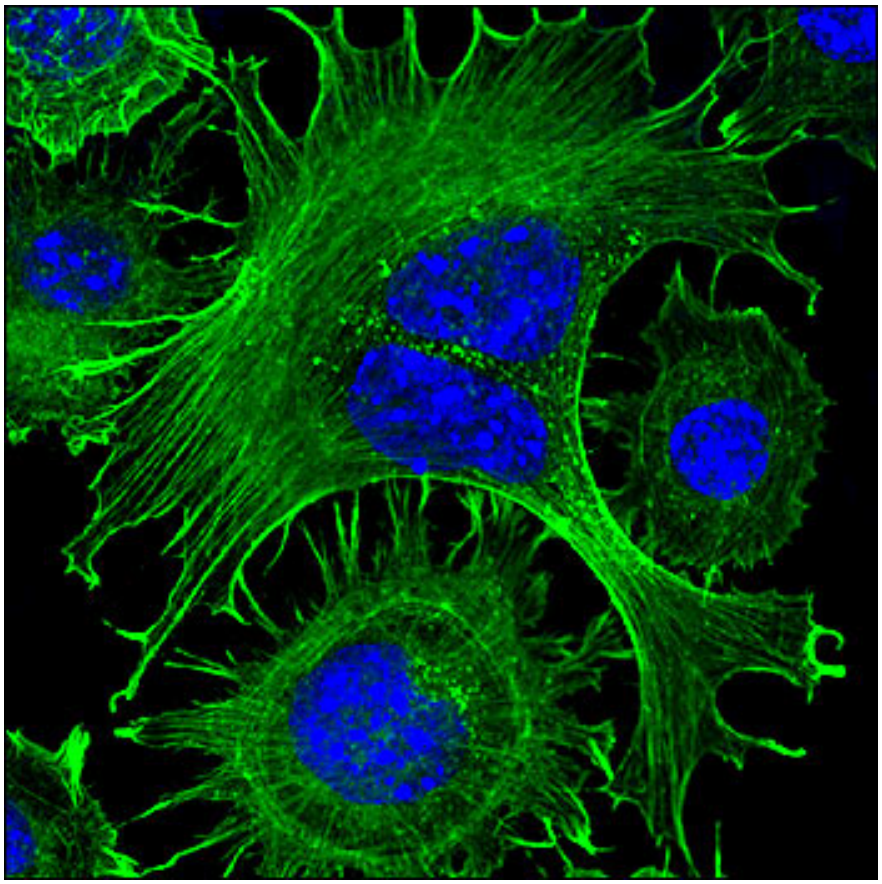
Historically, drawing was a key tool aiding observation, recording, and sharing in scientific disciplines such as botany, field zoology, anatomy, and geology.

Audubon's renderings of the bird species of North America have famously crossed the artificial divide between scientific and artistic visual productions. We respond to them esthetically as well as taking them as a source of ornithological information. We may even be, as students, attracted to the study of birds, professionally or as amateurs, by encounters with such images.

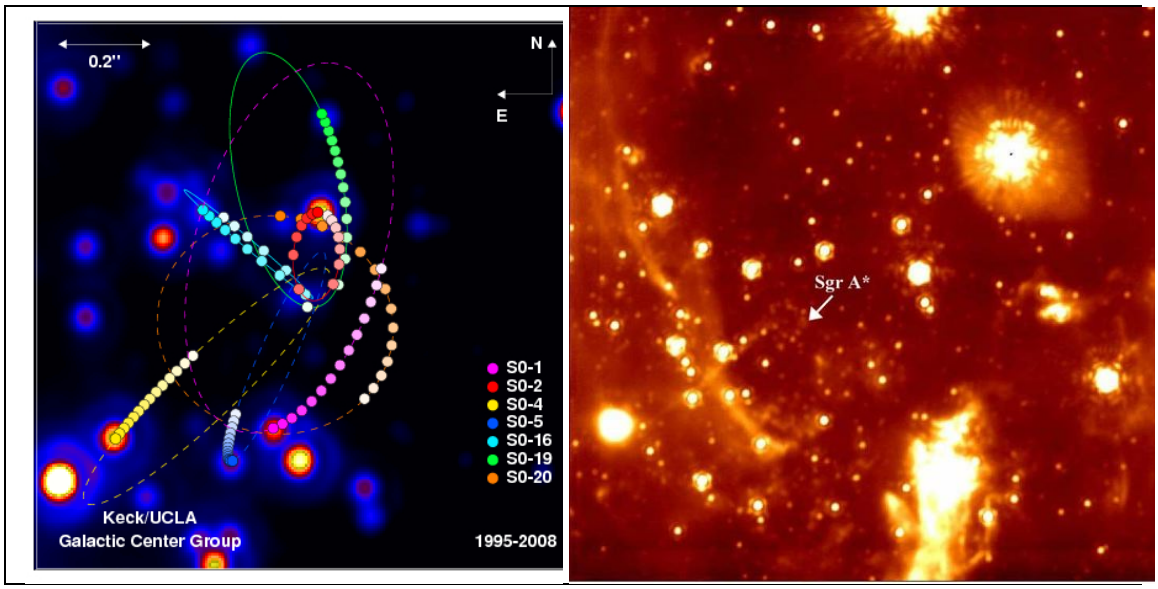
On the other hand there are many famous paintings of anatomical dissections, especially of human corpses, which while stylistically admirable can evoke feelings of disgust for their graphic content. Likewise, many medical images revolt some, fascinate others, and function more neutrally as sources of information for those who have learned to see them in this way. (It may well be that we should consider professional dispassionateness as itself an emotional or affective state, and in many cases a learned emotional response at that.)

The feelings of producers of such images may differ substantially from the feelings of various sorts of users/viewers who encounter them. The feelings that arise in production depend on the technology and medium of representation as much as on the genre or content. For example, in the plotting of a data graph, there is a certain amount of tedium, but it may be enlivened by the potential emergence of an interesting or significant pattern, by a surprising turn, or by uncertainties and anxieties over whether the data pattern displayed will turn out to support or refute a hypothesis, or simply be inconclusive.

Manual plotting with pen on graph-lined paper still occurs in some laboratories, as well as in student work, but increasingly such tasks are automated or computer assisted. The feelings are different when we interact with a graphing program to choose axes and scales, units and intervals, and perhaps re-display the same data in somewhat different ways. There may be less tedium, the same issues of anticipation and surprise, but now in addition our responses to the complexity of options (e.g. adding false color, photoshop effects), includings self-judgments regarding our competence (e.g. feelings related to pride, shame, bemusement, etc.).



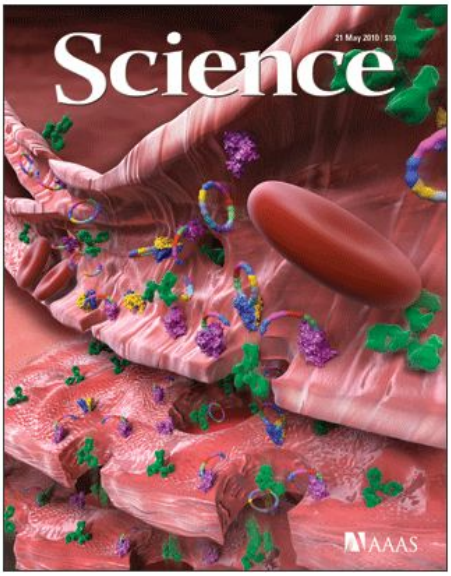
When dealing with complex data sets, there is a certain art to the process of "scientific visualization", some of it similar across traditional print and newer interactive media (cf. Tufte xxx), and some of it greatly aided by the options available in the new representational media and technologies. If we have data on the orbits of stars near the black hole at the galactic center (Ghez et al. xxx), we can choose which star orbits to show, over what time intervals, how to group them and show groups by contrasting colors, whether to animate the motions, whether to represent diagrammatically or photographically, which data sets to include or exclude, etc. As we see the results in real time of making various representational choices, we respond esthetically and emotionally as well as in terms of judgments of utility, accuracy, and faithfulness to the data.



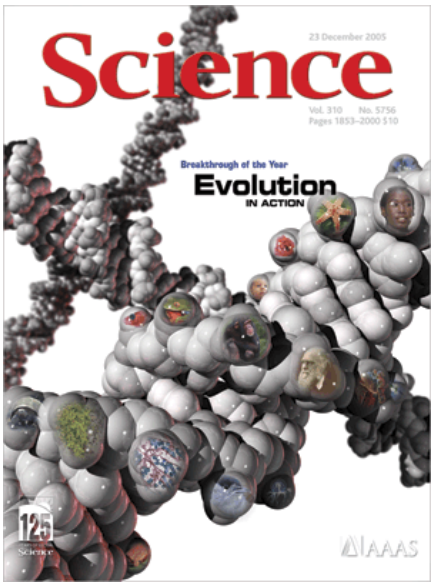
And we respond of course emotionally also to the content shown, to the patterns which are made through the process of producing representations (cf. Latour xxx), which may in some sense be implicit in the raw numerical data, but which have meaningful force in the community of science and beyond primarily when they are highlighted through our representational work (as for example with the pioneering work of Andrea Ghez at UCLA seen in these images, xxx, which helped establish the existence of the supermassive black hole, Sagittarius A, at galactic center, where previous work showed a much fuzzier and less conclusive picture).

The fuzzy boundary between scientific and artistic representations

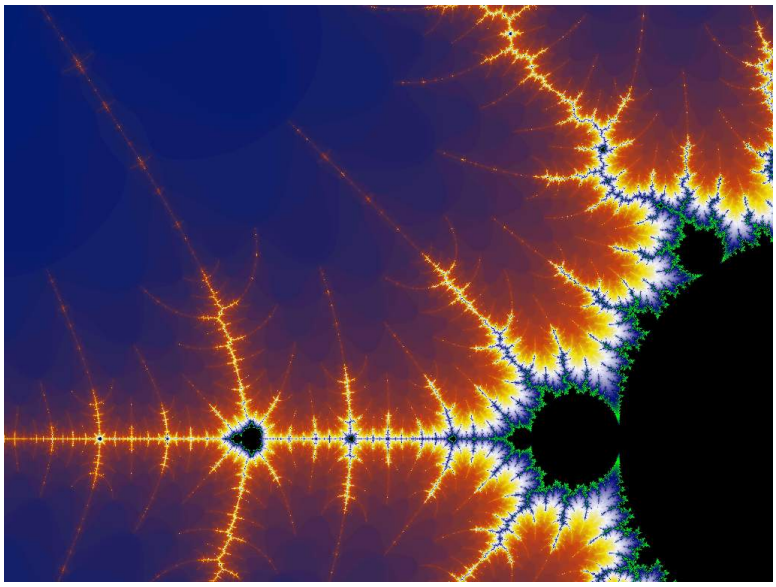
It should come as no surprise that we respond emotionally to visual images, whether considered as scientific or as artistic, given the long history in visual art of evoking a wide range of feelings. The work of some scientific research labs has also been marketed as abstract art, where the sheer beauty of the visual image (notably astronomical deep space images and mineralogical and some microbiological photomicrographs) is appreciated for its own sake. In most of these cases, what is seen is not raw data, but computer imagery or computer-enhanced (and often modified with false color or other effects) that may both enhance the salience of scientifically relevant features and also increase the general esthetic appeal of the images.



The covers of *Science* magazine, a serious scientific journal of important new findings, meant as well for wider appeal to the membership of the AAAS, with its broad focus on science and society issues, have for a long time used selected scientific images from papers published in an issue as the cover art for that issue. In more recent times, artists' renderings and creative variations on scientific images and themes have also been used. These images often deliberately blur the line between art and science, in keeping with the AAAS goal of promoting the impact of science on society and its integration into the broader culture.



These are also the goals of science education, but by and large the use of emotionally and esthetically appealing imagery, video, or simulations and games has been excluded from the teaching of science owing to a misplaced desire to portray science as a body of theory and fact, rather than as a human activity, and if as an activity, then as one where reason operates alone rather than, as we know to be the case, alongside the contributions of insight and feeling.



A particularly interesting case here is that of fractal imagery, such as the famous images the Mandelbrot set and its associated Julia sets, which, in various schemes to add color to them, are often felt to be exceptionally appealing and esthetically dramatic, even though they are generated from very simple algorithms and equations (by large numbers of iterations). Many natural phenomena which are visually appealing are also known to approximate fractal patterns (clouds, mountains, trees) and it is even conceivably possible that evolution has tuned us to some degree to have positive affect toward certain types of abstract visual patterns, patterns which occur in naked-eye-visible nature, but also in many other scientific domains where homologous mathematical relations exist.

Scientific representations in the wider cultural context of affect & representation

Apart from any evolutionary component, our feelings regarding representations arise within cultural traditions of modes, genres, and styles. Early modern science developed in a period of substantial and sometimes violent conflict over religion, philosophy, and politics, and in part as a result tried to frame itself as objective, dispassionate, and politically neutral. The polemics of the time certainly appeared in scientific communications and debates, and the boundaries that today separate science from religion, philosophy, and politics were not yet in place. In trying to extricate itself from a dangerously polemical environment, science also worked to exclude any influence in its official communications of appeals to the passions, to emotion and feeling. Only Reason was to be allowed, and later only reason based on empirical evidence (at least in the Anglo-Saxon tradition, Shapin & Shaefer 1985). It is taking some time for our cultural tradition to recognize now the complementary roles of reason and emotion, of meaning and feeling, in the process of scientific inquiry (e.g. Damasio xxx, Fox Keller xxx).

In relation to the learning of science and the recruitment to the scientific enterprise of new professionals and supportive amateurs, we also know that

many students are turned off to science because of its presentation (in curricula, textbooks, popular and news media) as not-about-people, not humane in the broad sense, unfeeling and anti-emotional, dry-as-dust, factual and boring. Mad scientists have considerably more appeal in the popular imagination than purportedly ideal scientists. This despite the fact that most scientists, when asked why they do science, generally give rather emotion-centered accounts of its mystery, grandeur, joy of discovery, pride in accomplishment, satisfaction of curiosity, and general esthetic appeal.

Younger children and young adults are attracted to scientific topics and themes, and to some scientific imagery and representations. Famously, to dinosaurs and galaxies. *Jurassic Park's* dinosaurs appear today in science and natural history museums in animatronic and 3D digital movie versions, vetted for scientific accuracy, but still much more appealing than what you'd be likely to find in a science textbook. Paleontologists work with computer-based simulations of the musculo-skeletal mechanics of dinosaur movements that are both more scientifically accurate and more like Hollywood's versions of living dinosaurs than the science presented in most school curricula. Both scientists and museum visitors find these new modes of representation more exciting.

Likewise, I think, with the example of the galactic core black-hole astronomy presented earlier, as with the wide appeal, extending even to posters and calendars bought for esthetic appeal of NASA and other deep space images, tweaked visually for both scientific and esthetic value.

I do not believe we know much about the gendered division in the appeal of various kinds of images, by genre and by content. Boys may be more drawn to dinosaurs, rockets, and galaxies than girls, or at least they were in decades not long past. Girls may prefer images of living things on a more human scale, whether mammals or not, though perhaps this is changing. In a pervasively gendered culture, where gender-based roles and expectations have been rapidly

changing, I introduce this issue mainly as another example of the need to take into account the wider culture's influence on how we feel about representations.

While science, perhaps in part from its history of competition with an older universalizing ideology (Christianity), tries to frame itself as culturally neutral, it seems more realistic to identify it as pretending to a universal culture of its own, but one which is fairly clearly middle-class and Western European. While the hegemony of this culture globally in the fields of science and technology gives it the appearance of universality, one has to wonder whether older Chinese and Japanese, or Islamic cultural traditions may re-assert themselves in time in shaping the future of the culture of science, and with it the norms of what counts as esthetically ideal forms of representation and the normative feelings connected with them.

Identity and Identifications

Culture appears in our actions, in the meanings we make and how we feel about our experience. A culture's norms, and those of a subculture like that of science, shape idealized identities: talking like a scientist, thinking like a scientist, feeling like a scientist. And identities are performed in significant part, and one may suspect also formed in large part, through processes of identification and dis-identification. What do we like? What do we like to do? What do we dislike? What kinds of music, clothing, food, friends, activities, images, movies, games? What kinds of science? What kinds of representations? Which technologies? Which genres? Which styles? What contents?

Consider the case of mathematical representations: numerical, algebraic, geometric. Some people feel good about all or some of these, and some people have very negative feelings about them that have a well-known impact on their interest in and learning about science.

$$\frac{\partial}{\partial x_i}\frac{\partial}{\partial x_k}A_i - \frac{\partial}{\partial x_i}\frac{\partial}{\partial x_i}A_k + \frac{1}{c}\frac{\partial}{\partial x_k}\frac{\partial \phi}{\partial t} + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} = \frac{4\pi}{c}J_k$$

$$\frac{\partial}{\partial x_k}\vec{\nabla}\cdot\vec{A} - \nabla^2 A_k + \frac{1}{c}\frac{\partial}{\partial x_k}\frac{\partial \phi}{\partial t} + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} = \frac{4\pi}{c}J_k$$

$$-\nabla^2 A_k + \frac{1}{c^2}\frac{\partial^2 A_k}{\partial t^2} + \frac{\partial}{\partial x_k}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial \phi}{\partial t}\right) = \frac{4\pi}{c}J_k$$

$$-\nabla^2 \vec{A} + \frac{1}{c^2}\frac{\partial^2 \vec{A}}{\partial t^2} + \vec{\nabla}\left(\vec{\nabla}\cdot\vec{A} + \frac{1}{c}\frac{\partial \phi}{\partial t}\right) = \frac{4\pi}{c}\vec{J}$$

Should we not then assume that people also have strong feeling-based preferences regarding verbal descriptions and explanations vs. visual representations? And likewise for expository vs. narrative text, for still images

vs. dynamic ones, for realistic images vs. abstract diagrams? While this topic has been extensively discussed in terms of *cognitive* styles and preferences, with a focus on outcomes, we pay much less attention to its affective dimensions and a focus on origins and processes (in which the cognitive and affective are expected to interact pervasively).

Part of the scientific habitus (Bourdieu xxx), the scientific identity, is a positive affective disposition towards most or all of the conventional technologies, media, genres, and styles of representation within at least some scientific sub-discipline. It is part of what it means to be enculturated into science. As much as that enculturation includes learning to talk science, read science, do science, it also includes particular ways to feel about talking, reading, and doing science. And consequently, also particular ways to feel about making and using representations in science.

Future of Representational Media and Forms

A concern with the affective dimensions of our use of representations is also relevant to the design of new representational genres and their technologies and media, both for professional and amateur use in science, and for the teaching and learning of science.

Again it is important to take into account that how we feel about representations and media genres is in significant part a function of the wider culture. Today, for example, computer games and especially their relatively realistic, navigable, interactive, and increasingly social 3D virtual worlds are important sites in which we are developing expectations and feelings about new media and representations. The games focus significantly on affective responses: amazement at complexity and graphic realism, anxiety about virtual dangers, elation at virtual achievements, pride at achieved status in virtual communities, shame over failures in online social worlds. Joy and excitement drive gaming far more explicitly than they do science, especially learning in school science. While

joy and excitement do motivate working scientists, they are acknowledged only outside the hyper-rational culture of science as a knowledge community. In schools and in science the puritan notion that work and pleasure are opposed to one another has had far too much influence.

The creation of new tools for making and using representations has passed largely into the hands of design specialists in fields such as Human-Computer Interaction, and there we do find an increasing concern with "emotional computing" and with the feelings associated with using various interface representations. There is a sense that interacting with a computer, or with a program, should be like interacting with another person, in which we recognize that the emotional response of the other is important to sustaining effective and comfortable, even pleasurable, interactions.

If we look back to older technologies of representation, there is no doubt that many people find pleasure in reading and in writing, some of which is content-dependent, but in many cases the medium itself and its associated practices clearly also contribute to the pleasure. Some people love working with mathematical notations, many love to draw and to paint, a "love of books" is proverbial. The criteria by which we choose modes of representation are not merely utilitarian ones, they are also esthetic and affective ones. Identifications with media and practices are deep-felt aspects of our personal identities.

Doing research on how people feel about modes of representation is difficult. We lack a common vocabulary for describing such feelings, much less a systematic theory of affect and its role in meaning-making. It is also not clear whether or not we ought to try separating the impact of content on our feelings from that of the mode (technology, media, genres, styles) itself.

Learning and Feeling

I think it is important to at least sketch out a more holistic and phenomenological framework for talking about the role of feeling in meaning-making. While this is in itself a major project beyond the scope of this discussion, a few key principles may make the relevance to the learning sciences of some of the foregoing analysis more evident.

Feeling, I believe, arises as an intrinsic aspect of action, of doing, moving, interacting within a rich material and semiotic environment. We do not ever *not* feel something. Every state of being, of doing, of living, is accompanied by, is partially defined by how we feel in the process of doing. Such feelings are phenomenologically, experientially, highly specific. They can always be differentiated in retrospect from how we feel in other activities. In fact, I believe that the feeling of every moment in life is unique.

Culturally, we learn to broadly categorize feelings. English has hundreds of terms for categories of feelings and many expressions of the type: I feel … (e.g. happy, proud, nauseous, tired, angry, afraid, surprised, etc.). Some of these emphasize

the somatic aspect of how we feel (nauseous, tired). Others are canonical emotions that are responsive to specific external objects (angry at X, afraid of Y). And many are self-evaluative, appraisals of ourselves: I feel confident, shy, guilty, remorseful, proud, noble, etc.

We develop dispositions for broadly positive or negative feelings about types of actions, activities, people, and objects, and about topics, technologies, media, genres, and styles of representation and matters represented. Such feelings carry a sense of greater or lesser intensity by degree, as well as the particular experiential coloration of the instance, the moment, the present context.

In regard to learning, the activity of learning something specific has its own feeling dimension, which arises in response to what we are doing in order to learn, what we are learning about, what tools we are using to learn and how we are engaging with them. Learning, moreover, is itself a rather invisible phenomenon as a process. Explicitly, we backtrack along the trajectory of life to attribute to some actions and experiences the origin of new ways of talking, doing, feeling, etc. that are themselves observable later on. Many things that we imagine have been "learned" turn out to be transient, not learning that lasts or shows up again and again over the longer term. The learning which matters is learning that lasts: learned practices or feelings that have visible influence in later action, again and again.

Feelings may function in some respects as the glue or common element across different occasions of experience, and which helps us to tie them together. So also with learning that lasts: how we feel when we again and again do or use something learned in the past is part of why we feel a continuity between (retrospectively construed) originary learning experiences and later instantiations or repetitions, variations, and transformations of what was learned.

In relation to the complexity of making and using representations, dispositions toward and sensed continuities of feelings may apply to the technology (pen and paper, keyboard screen and mouse), the semiotic modality (language, depiction, gesture, etc.), the medium (books, videos, interactive games), the genre (textbooks, documentaries, shooters), the thematic content (dinosaurs, galaxies, China), and the work (this textbook, that video).

Designers would, no doubt, like universal guidelines for producing media that evoke positive affective responses, that people enjoy using. This seems unlikely, however, given: the variation in users' backgrounds (social, cultural, biographical, temperamental); the combinatorial effects of feelings regarding technologies, media, genres, content, etc.; and the effects of embedding activities and contexts (situational and temporal). Both teaching and design are ultimately arts as well as sciences; that is, they must deal with the particular as well as with the general. We can say in general what teachers and designers should pay attention to, but they must learn by experience, to the extent possible, how to respond to each unique instance (each student, each teachable moment of opportunity; each user's preferences, each larger context of use of a tool).

To ground any helpful advice about either the general or the particular, we do need to accumulate more collective knowledge about how people feel when using various tools, media, and representations. And to do so with attention to variation across individuals, communities and cultures, genres, contents, styles, and contexts.

In doing so, we need to work towards understanding the unitary process of meaning-and-feeling, so that, just as we have come to understand about what is variously called "meaning making" or "cognition", we recognize that feeling also needs to be framed as an active process, as situationally contextualized, distributed through a material environment, socially interactive, and culturally shaped. Feeling also is both materially and semiotically mediated, just as it in turn mediates which tools we select and how we use them, as well as which people we work and learn with and how we interact with them.

In every disicipline we have not just feelings about what we study, but we seek to gain a feeling *for* these phenomena, these organisms. A feeling for what we study is mediated by the feelings we have about and for the representations we use as tools to study it and as means to communicate what we have learned. As such, the affective dimension of our engagement with representations and representational practices seems essential to an effective understanding of the learning process itself across its many timescales.

Appendix: A Note on Terminology

Although in general I believe that the meaning of terms has to emerge from the ways they are used in discourse, rather than being dictated by a priori definitions, many terms used in this discussion have quite different usages in different traditions. A few clarifications.

I use the term "modality" in the sense of a *semiotic modality*, that is a specific cultural system of symbolic resources for making meaning whose units have relations of contrast or similarity to one another (paradigmatic relations) and which are deployed in spatial or temporal arrays which assign them additional relations (syntagmatic relations) relevant to the meaning of these larger units. Thus a language is a semiotic modality, and so is a cultural system of gesture or depiction. Semiotic modalities are also called semiotic systems, and they should not be confused with sensory modalities (sight, hearing, touch, etc.).

A *medium* is the material basis for some symbolic expression, the material object(s) whose physical manipulation leaves more transient or more persistent traces that can be recognized as signs in relation to some semiotic modality and its customary cultural uses. Printed paper, painted canvas, dancing bodies, illuminated screens.

It is often difficult to separate a medium from the whole *technology* by which signs are created and displayed in it, meaning by the technology all the materials and practices which contribute to this process. Video technology, pen-and-paper technology, photographic technology. In this sense, film technology is distinct from video technology, even though it is possible to display their symbolic contents in the same medium, or in media that can be put in one-to-one informational correspondence.

A *genre* is a set of conventions regarding the form of a symbolic product (aka semiotic work), which in general dictates the arrangement of components and the type of content appropriate for each component. A folk-tale or haiku is a verbal genre; a sonata a musical genre; a self-portrait or landscape a genre of art painting; data graphs and circuit diagrams are visual genres common in scientific practice.

Finally, *representation* itself. I use this term essentially as synonymous with a symbolic product or semiotic work: any materially embodied array of physical features that can be recognized as having a conventional meaning in relation to one or more semiotic modalities and their typical cultural uses. I do not accept either the idea that representations re-present some independent reality (since they are commonly used to present meanings with no other corresponding objects, e.g. hypothetical cases), or the notion that a representation in itself indexes or points to some separate reality (because some interpreter is always needed to make any connection to anything else). It is of course possible to make such connections, and there are cultural conventions as to how this should be done, which connections have what kinds of meaning or validity, etc.

Scientific representations tend to be either *inscriptions* (in Latour's sense): traces in some medium of the action of natural phenomena, but so contrived (by the recording apparatus) as to be interpretable as signs by some system of semiotic conventions (e.g. seismographic traces), or they are transformations (Latour's *translations*) of inscriptions into other genres (e.g. maps, data graphs), or they are hypothetical *proposals*, which are to be interpreted as possible relationships among abstract features of natural phenomena (e.g. theory-based graphs, formulas, schematics, models, simulations). This is the narrow sense. In a broader sense, there are of course many other kinds of representations which function as tools in the doing of scientific work.

Representation is also, and for many purposes more fundamentally as I wrote at the beginning, a process: the making and using of "representations" in the sense immediately above. For some purposes this process sense may be referred to as *representational practices*.