

# Prospectus

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## Abstract

This is a project about the social and technological contexts that support learning. It deals with questions about how to make technologies that adapt to users and that users can adapt to their needs. The work itself is a sort of dynamic anthropology, and is concerned with the range of issues that apply in real learning communities. The project's development goals include a new system for web-scale collaboration, and specialized tools to support computer-mediated interactions with mathematics. Mathematics and other special cases will be used to approach the main question: *how do learning communities work in practice?*

## I

**Introduction** I'm going to describe this project in terms of *context, motivation, resources, freedom, questions (or theories), and actions*. These dimensions could frame any discussion about how social systems evolve; but they seem particularly suitable for talking about *open learning environments*.

For example: *PlanetMath's* developers might want to *install* or *create* some new *forum software* so that we can capture more precise *semantic relationships* between questions and answers, or between messages and encyclopedia articles. We *can do this* whenever we *feel like it* – but it's not true that just anyone can. If

*for whatever reason* we don't do it, users who get fed up with PlanetMath's disorganization *can leave* and talk about math somewhere else! In fact, anyone can *reuse and redevelop PlanetMath's software* to do this, but if the project is ever *forked* in this way, the *community* would restructure itself around the new *resources*.

*In the rest of Section I, I'll use this intuitive vocabulary to sketch my project in broad outlines. In Section II, I'll connect the sketch to some important contemporary research themes. In Section III, I'll do a preliminary survey of the related literature. In Section IV, I'll get into the details of my proposed development work. In Section V, I'll clarify my research questions. And in Section VI, I'll detail the work schedule.*

**Systems and objectives** One could think of an objective as either “noun-like” (the state one wishes to attain) or “verb-like” (the action one wishes to accomplish or perform). It's important to notice that many things (by definition, *noun-like*) are undergoing evolution. This evolution is often essentially purposeless. By contrast, *verb-like* actions tend to be purposive. When speaking of the goals of this thesis project, I will attempt to speak about things I want to *do*. For instance, a concrete objective is to

- (1) *build a place where people can effectively learn and study high-level mathematics online.*

As time goes by, we will of course want to *determine just how effective the system really is at supporting mathematics learning!*

**Questions and evaluation** Objective (1) is an example of *a broader set* of goals that have to do with *studying* and *supporting* learning. (The basic questions are: What is learning? What potentiates it?) It will be important to design our study so that *evaluation events* will occur at useful intervals. Evaluating the way a *system* evolves is a bit like sketching the level set of a function in several variables, or like deciding where to put in break points when debugging code. The choices we make about where and how to do evaluation will depend, on the strategy level, on the *questions* we're trying to answer in the context of *systems that support learning*, and on the tactical level, on exigencies related to *development*. Ideally, during the course of this study, we will be able to

(2) *explicate the range of issues that apply to the design, use, and ongoing collaborative development of systems that support self-directed or peer-based learning.*

**Modules and maps** When *designing* a new system, *surveying an extant one*, or *strategizing* about how to modify any collection of resources to achieve certain goals, it is of course helpful to analyze the system (or potential system) into its several (or many) *component parts* or *modules*. In the course of a research project, "*theory*" can even play the role of so many modules (e.g. a machine that takes in data and produces statistics, a strategic plan that tells you what actions are worth supporting, or a philosophical framework that tells you what questions are worth asking).

When (re-)designing a software system, some of the modules may be available as *off-the-shelf tools* and won't need to be developed or even maintained by hand. However, since many such tools are themselves undergoing their own evolution, maintaining them as *a set of interoperating components* may be a serious ongoing challenge. The most useful maps, will, therefore, take the temporal dimension into account.

We begin with the idea that knowledge is a map, in other words, knowledge is always embodied in a "knowledge medium". This idea of knowledge-as-map and map-as-knowledge will inform everything we do.

(3) *Quite simply, we will use a modular systems design. This applies to code, workflows, and theory. If the pieces we need aren't developed yet, we should be able to say "I want something that does something sort of like this, here".*

**Premise: Context constrains action** Every context will support some actions and make others hard or impossible. For example, we tend to think of the teacher/student relationship as a context that supports learning. Contexts overlap and nest, so, for example, the teacher/student relationship is embodied in cultural practices related to physical and institutional environments. It seems to me that every *context* constrains the *ways in which people relate to one another* to some degree.

(4) *Without neglecting the importance of individuals or relationships, for the moment I want to make context or landscape central, and examine the ways in*

which it constrains or supports different types of (inter-)actions.

**Premise: Freedom is ambiguous** Our freedoms are often phrased negatively: “if you don’t like it, go build your own” – or, more bluntly, “love it or leave it, bub.” Some people think freedom is a simply a myth [39]; others think it is really, really, important [54]. Or, on a somewhat cynical view, maybe it’s both.

(5) I will choose to understand “freedom” as ambiguity, i.e. as the state of being undetermined. This begs the question as to just what things are determined, and how!?

**Premise: Motivation is key** Human motivations being what they are, we seem to always have a lot to learn.

(6) If we can really understand motivation, everything else will become clear.

## II

**Ontological foundations** Assemblage theory, as explicated by DeLanda [11], after Deleuze ([14], [12], [13]), has everything to recommend itself. There may be some additional work left, but it has already been connected to semiotics [20] and hypertext [6], so I think we’re well on our way with this beginning.

**R&D** The ROLE project’s reports (D1.3/D1.4 [7], D3.2 [48], D3.3 [58], D4.1 [47], D7.1 [41], and D7.2 [40]) cite a massive body of literature. For the moment I’ll single out [53], cited in [40], because it provides one epistemic model that bears on learning. It will be interesting and useful to examine the ways in which this model may or may not jibe with assemblage theory. The ROLE project’s current body of work will be the foundation for the next round of literature review.

It would be helpful to attune my own schedule to the development schedule for ROLE whenever appropriate.

**Making meaning** Mathematics is an example of an inherently multi-modal subject area, and many different “literacies” are relevant to experiencing and producing meaning(ful interactions) in this field (see [35], cited in [24]). We’ll also want to return to the semiotic thread [21], to look at just what “meaning” means.


**Ba** The idea of shared context in motion (*basho*, 場所 in Japanese) is dealt with extensively by some of the progenitors of the “knowledge management paradigm”; see [43]. The usefulness of this model is reviewed with some strong (perhaps even harsh) criticisms in [23], though its popularity may to some extent counterbalance this critique. The foundations of this understanding of place (*ba*) begin with the philosophical work [42] (summarized in [1]). *Ba* will provide a nice way to dig into I.(4).

**Databases and Semantics** I’m interested in understanding the best ways to use databases [9], persistence, role-based [29] (as opposed to object-oriented) computing, and understanding in detail how this blends with semantic web technologies (e.g. triple stores etc.) and “semantic network paradigms” more generally.

Installing and reading the documentation for standard triple stores, and seeing how they compare to “The Third Manifesto” for relational databases (i.e. [9]) seems a reasonable beginning, connecting both practice and theory.


**The architecture of apocalypse** Derrida has written about an apocalyptic tone, whose effect on conventions is to disrupt and destabilize them ([15], cited in [33]). I’m interested in a sort of “architecture” based on this principle, an architecture of

“intersections, in-between spaces, and unstable sites” (ibid.). I hope to relate these themes to more mainstream ideas from architecture and urban geography ([26], [27]), and develop them into a technique that will be useful when exploring many different mediated environments.


 How do associations work in the brain? What are “creative” mental states? How do they relate to “structured thinking”? How and when is it useful to use computers to explicitly model the way humans think? In order to be able to answer these question in an even remotely useful way, I think it will be necessary for me to continually give critical examination to my own creative work as this project progresses!

### III

**Tech** Sidewiki [31], Shiftspace [49], Seaweed [44], Etherpad [30], 4store [30], Redland [2], Delicious [32], Semantic MediaWiki [36], MUPPLE [59]


 There’s probably no end of “relevant” technologies, but now that we’re starting to have a sense of this project’s objectives, we can use existing technologies as a sort of “grid” on which to trace out our own designs.

**Commons** Luís Correia, José Castro Caldas and Nuno Teles *Freedom in knowledge creation* [8], Marshall McLuhan and Bruce R. Powers *The Global Village* [38], Friedrich A. Hayek, *The Use of Knowledge in Society* [25], Emile Durkheim, *The division of labour in society* [19]

 Note that for big or complex projects, being “modular” is not enough; people need to be “collaborative”. Commons tend to follow certain well-known patterns (e.g. the Zipf law); they

have, also, a whole anthropology or ‘koinomics’, unto themselves.<sup>1</sup> *Understanding commons has everything to do with the way people think about “property”, which in turn brings up some Humean questions about how collective imagination works. We may find the most basic “commons” in human language [50] (or not! – [55]).*

**Systems that learn** John Dron, *Achieving self-organisation in network-based learning environments* [17], Martin Dougiamas, *The use of Open Source software to support a social constructionist epistemology of teaching and learning within Internet-based communities of reflective inquiry* [16], Peter L. T. Pirolli, *Information Foraging Theory: Adaptive Interaction with Information* [51], Stewart Brand, *How Buildings Learn: What happens after they’re built* [5], Rick Kazman and Hong-mei Chen, *The metropolis model: a new logic for development of crowdsourced systems* [34]

 Since there is a huge literature here, it may be fruitful to focus on one facet of the question, and look at how systems raise their level of abstraction or complexity. For example, think of Walmart transforming itself from a country store to an international mega-corporation. Does more complexity just mean “more inputs and outputs”? We can also ask the meta question: why has so much been written about learning!?

**Psychology** D. D. Olds, *The behavioral schema: an integration of modes of learning* [46], Marvin Levine, *Effective Problem Solving* [37]

<sup>1</sup>See <http://dlc.dlib.indiana.edu/dlc/>.

✎ Bring some psychological perspectives to bear on how people learn or do math etc. For example, compare the psychologist Marvin Levine on problem solving with Pólya's famous books on the subject.

**Understanding structure** Mark Steyvers and Joshua B. Tenenbaum, *The Large-Scale Structure of Semantic Networks: Statistical Analyses and a Model of Semantic Growth* [56], Tim Van de Cruys, *A Non-negative Tensor Factorization Model for Selectional Preference Induction* [10], C. Biemann, *Ontology learning from text* [3]

✎ *Implicit structures are sort of like 'anamorphic drawings' or steganography – you have to look at them the right way to see that there's anything there at all! E.g. when first examining a document, we don't automatically see the patterned appearance of its n-grams or other interesting things like that; when first looking at the web, you don't see PageRank. It takes some insight to know what to look for, and some work to find the patterns once you get an initial clue.*

**Semantic Adaptivity and Social Networking in Personal Learning Environments** Chao Boon Kheng Leng Teo and Robert Gay *Concept map provision for E-learning* [57], Herbert Blumer *Symbolic Interactionism: Perspective and Method* [4], John Dron, *Control and Constraint in E-Learning: Choosing When to Choose* [18]

✎ *Review everything related to making ideas explicit, sharing them, rearranging them together with others (building a better conversation), etc. How*

*can this process be personalized and negotiated? (Interview the originator(s) of the phrase "Semantic Adaptivity and Social Networking in Personal Learning Environments" to see what they think!)*

## IV

**Structure** Add "semantic" features to content, where applicable, to design learning objects which possess certain standard metadata and which thereby fulfill certain objective standards for quality [28]. E.g. OMDoc "serves as semantics-oriented representation format and ontology language for mathematical knowledge"<sup>2</sup> that has been modified for use in an educational context [60].

✎ *Whenever possible, we should generate these things automatically, so as to integrate with existing workflows. Ultimately, we'll want some "structured search" tool(s). (If we take "mathematics" as one case study, how does it differ from e.g. "coding", or other topics?)*


**Cluster** Discern useful things to bundle together e.g. for further structuring or to discuss or transform in bulk. Often structures are in fact explicit but still not clustered for purely historical-technical reasons. Techniques for labeling objects or flows basically expand upon the "knowledge cartography" idea [45]. (If we can say what constitutes "an object", perhaps we can also say what defines "a context"?)

✎ *There is currently no high-level graphical map of e.g. Wikipedia or Connexions or PlanetMath (and limited commandline interface, at least in*


<sup>2</sup><https://trac.omdoc.org/OMDoc/>

the PlanetMath case) – no obvious sense in which their design or use patterns are “modular”. This is automatically complicated in light of the fact that different users would tend to cluster the same set of data differently.


**Share** Move links, comments, and objects between contexts, based on user and group preferences and profiles.

 (This is where I see the biggest gap.) Sidewiki exists, but there is no way to bend the web around the contributions you’re interested in. There are a lot of details that need to be added to develop this idea of “bending”, but the metaphor comes from general relativity: a heavy body changes the way light flows around it. Similarly, on the web, an object of interest should change the way data flows around it.

**Trace** Anything we can learn about users and groups can be used to shape their operational context.


 How can we use existing data (flows) about user interactions (e.g. browsing/editing patterns for Wikipedia users, data saying which online groups a user participates in, or which data feeds they subscribe to)? How can we identify new useful data flows?

**Speak** Support question-asking and answering, and interactions that change the very nature of the discourse space.

 Arxana is specifically designed to be a tool to facilitate “changing the nature of the discourse space”.<sup>3</sup> It refuses to be


an ancillary space and aims instead becomes a general tool for “hacking the system” (any system). Even as this becomes infinitely complicated, some simple things – like setting up a proper issue tracker for PlanetMath – can be done right away!

**Scaffold** Make tools that help people connect everything in useful, ability-strengthening, ways.

 Can we give feedback to say when learning is taking place? Can we fill in intermediate steps to help people reach their goals? (Cf. Vygotsky, right?) Technological and social change should, presumably, occur whenever people keep encountering the same problems over and over again. Obviously, no learning takes place “in a vacuum”, and, furthermore, learning comes bundled with an at-least-implicit strategy. These strategies may sometimes be sharable as “Open Educational Practices”<sup>4</sup>.

## V

**How much?** Resources appear within a broader pattern of use. E.g. reference material is used by someone trying to solve some problem. How much of this “context” do we need to support?


 When McLuhan said “the medium is the message”, he was talking about technology. But, in the spirit of “space is the machine” [26], I have to wonder if the moment – which includes everything that’s happening! – isn’t the real medium, so we can sum up, “right now is the

<sup>3</sup><http://metameso.org/files/unstable-arxana.pdf>


<sup>4</sup><http://qualityoer.pbworks.com/FrontPage>

message". As a simple example: a tagged text means something different from the same text without tags, and may not even be readable without them. The idea that we can understand events apart from their context is highly dubious. And yet, this ultimately describes the challenge of knowledge representation: to understand what we can represent with text alone (on the computer, it's all text).

**How to?** "Broad patterns of use" include the processes or "complex links" that move the system from one state to another. What data about these activity patterns is available, and how can it be used to make things work better for people? Sometimes complex activities can be opened up and modified on the fly. Usually they're just not that well understood.


 Make a diagram of the actions that comprise the processes we're interested in.

**Changing how** In the first place, it will be useful to make/find some tools to understand trends in writing, communication, or correspondence over time (e.g. so we can think of linked structures as proto-ontologies). But once we know what the structures are, how can we change them to better support learning and adaptation?


 What is the relationship between "understanding trends" and "making changes"? It has something to do, surely, with the psychology of assertiveness. But I'm not so sure that's something we can treat as a block. For example, patterns and aesthetics (matters of personal or cultural taste) guide us in making decisions. How should we understand changes "within the

game" as opposed to "complete game-changers"?

**How best?** Look at contexts to determine their goals, or vice versa, look at goals to determine suitable contexts. What tools are suitable for what purposes? For example, "firm" versus "commons" – and generalizations of these – when is decentralization or centralization more appropriate? We can begin with a simpler question: how to state what you want in the most suitable context? (E.g. by using the right sort of "bug reporting mechanism".)


 There is a conflict resolution, negotiation, and policy development side to all of these things, which suggests a that we may want to follow up on the game theoretic treatment of "knowledge" (cf. [22]).

**Adapt or evolve?** People keep running into the same roadblocks and asking the same questions. How does this relate to technological growth, cultural change, or individual learning? Document "the way systems learn" – and say something about their general evolution. How do platforms meta-cognize? How do groups reflect, or solve adaptation problems? How does adaptation differ from evolution?

 For one thing, both adapting and evolving aren't just "consuming" (waiting for something new to come out and then buying it). As we look at reactions to change, we see some people get excited, and others are wary. (For example, pedagogues to worrying about students using online content to cheat; technologists getting excited about building better tools to apply to real world problems.) The way groups and cultures change or resist change is wrapped up

*with the way individuals behave. Can we develop one coherent picture of purposive individual and social change?*

**How to hack?** How could, would, or do people use wikis, or things “like” wikis, for learning purposes? This has to do with the question: what’s “like” a wiki? – And, also, what’s (beneficially) *unlike* a wiki, e.g. when it comes to hacking, or running, code?

 *Using what we know about the different “property” (or is it “content”? – or “learning”?) management systems used by e.g. hackers, teachers, researchers, or students; and what we know about problem solving – it would be great to have a “How to Hack It” book that updates Pólya’s classic “How to Solve It” [52] for use in a social, online setting.*

## VI

**Conclusion** The institutional context provides lots of sources of feedback, and consistency across temporal and other dimensions.

To compliment and interface with these resources and inputs, I want to begin by imposing some useful frames over the field I’ll be studying. For example, assemblage theory, *basho*, and Jon Dron’s framework for the design of e-learning will all be useful for thinking about and specifying the various features of existing, hypothetical, and prototype systems and approaches. I’ll also want to ground my project in technical specifics as much as possible. This should come from very practical experiments with existing systems, combined with selective forays into formal theory when applicable. The first year has to do with building a practice and a framework that will provide feedback. By the time the first year is over, I hope to have a reasonably clear picture of what’s

there in the domains I’ll be dealing with, some clear proposals, and good sense of why my proposals are a good idea.

Once this frame is ready, I’ll continue to map out from the core, as the work grows to real social spaces, and as new patterns come into view. Answering remaining theoretical and practical questions will be important milestones. In particular, it will be vitally important to align the work with broader social agendas. Both critical analysis and instructional guides (presenting what I’ve been learning, in a clear way) come into play at this stage. The second year should culminate with a “programmer-ready” specification, and perhaps demos, key deliverables like GravPad and the “PLE IDE”.

By the end of the project, it will be time to fulfill the project’s major goals: to give an account of how mathematics works in our culture, and some reflections on how it can work better. Similarly, to say how communication works in various contexts, and how technology can be used to improve learning and other purposive collaborative activities.

<b>Date</b>	<b>Deliverables</b>
2010 Q1	<ul style="list-style-type: none"> <li>* This prospectus</li> <li>* Etherpad widget</li> <li>* GravPad mockup</li> </ul>
2010 Q2	<ul style="list-style-type: none"> <li>* Tech survey</li> <li>* <i>Ba</i>-based design of goal system(s)</li> <li>* GravPad demo</li> </ul>
2010 Q3	<ul style="list-style-type: none"> <li>* Survey <i>après</i> ROLE</li> <li>* Survey paper on data management</li> <li>* Position paper on “freedom” in computing and learning</li> </ul>
2010 Q4	<ul style="list-style-type: none"> <li>* Describe relevant activity patterns</li> <li>* Review models, ontologies</li> </ul>

Table 1: The first year

<b>Date</b>	<b>Deliverables</b>
2011 Q1	<ul style="list-style-type: none"> <li>* Empirical treatment of “context”</li> <li>* Whitepaper on “collaboration”</li> </ul>
2011 Q2	<ul style="list-style-type: none"> <li>* Review society’s education needs</li> <li>* Toolset for clustering and classification</li> </ul>
2011 Q3	<ul style="list-style-type: none"> <li>* Can a computer learn?</li> <li>* “How to hack it” monograph</li> </ul>
2011 Q4	<ul style="list-style-type: none"> <li>* Heuristics for recommendation</li> <li>* PLE IDE spec</li> </ul>

Table 2: The second year

<b>Date</b>	<b>Deliverables</b>
2012 Q1	<ul style="list-style-type: none"> <li>* Visualization</li> <li>*</li> </ul>
2012 Q2	<ul style="list-style-type: none"> <li>* An anthropology of mathematics</li> <li>*</li> </ul>
2012 Q3	<ul style="list-style-type: none"> <li>* Knowledge = cartography?</li> <li>*</li> </ul>
2012 Q4	<ul style="list-style-type: none"> <li>* Artist’s statement</li> <li>*</li> </ul>

Table 3: The third year

## Bibliography

- [1] Masao Abe. Nishida's philosophy of 'place'. *International Philosophical Quarterly*, 28(4):355–371, 1988.
- [2] Dave Beckett. <http://librdf.org/>.
- [3] C. Biemann. Ontology learning from text: A survey of methods. *LDV Forum*, 20(2):75–93, 2005.
- [4] Herbert Blumer. *Symbolic Interactionism: Perspective and Method*. University of California Press, 1969.
- [5] Stewart Brand. *How Buildings Learn: What happens after they're built*. Viking, 1994.
- [6] Kathleen Burnett. Toward a theory of hypertextual design. *Postmodern Culture*, 3(2), 1993. <http://www.iath.virginia.edu/pmc/text-only/issue.193/burnett.193>.
- [7] Arunagsu Chatterjee, Effie Law, and Katrien Verbert. Functional requirements analysis and specification; non-functional requirements analysis and specification. Technical report, ROLE project, 2009. <https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38397744/D1.3-1.4-Draft-Ver1.07.doc>.
- [8] Luís Correia, José Castro Caldas, and Nuno Teles. Freedom in knowledge creation. In *Workshop sobre Ciências da Complexidade: Mathematics and Innovation, ciclo de Encontros da Arrábida, da Fundação Oriente, Convento da Arrábida, Portugal*, 2006. Preprint available at [http://www.listaweb.com.pt/icc/textos/Arrabida\\_2006\\_Correia\\_Caldas\\_Teles.pdf](http://www.listaweb.com.pt/icc/textos/Arrabida_2006_Correia_Caldas_Teles.pdf).
- [9] C.J. Date and Hugh Darwen. *Databases, types, and the relational model: the third manifesto*. Addison-Wesley, 2006. 3rd edition.
- [10] Tim Van de Cruys. A non-negative tensor factorization model for selectional preference induction. In *Proceedings of the EACL 2009 Workshop on GEMS: GEometrical Models of Natural Language Semantics*, pages 83–90, 2009.
- [11] Manuel DeLanda. *A New Philosophy of Society: Assemblage Theory and Social Complexity*. Continuum, 2006.
- [12] Gilles Deleuze. *Foucault*. Paris: Les Editions de Minuit, 1986. translation, Seán Hand (2006). Continuum Impacts.
- [13] Gilles Deleuze. *Empiricism and subjectivity: An essay on Hume's theory of human nature*. Columbia University Press, 1991.
- [14] Gilles Deleuze and Félix Guattari. *Mille Plateaux*. Paris: Les Editions de Minuit, 1980. translation, Brian Massumi (1987). *A Thousand Plateaus*, University of Minnesota Press.
- [15] J. Derrida. Of an apocalyptic tone recently adopted in philosophy. *Se-meia*, 23:63–97, 1982.
- [16] Martin Dougiamas. The use of open source software to support a social constructionist epistemology of teaching and learning within internet-based communities of reflective inquiry. Work in progress at <http://dougiamas.com/thesis/>.
- [17] Jon Dron. *Achieving self-organisation in network-based learning environments*. PhD thesis, University of Brighton, 2002.
- [18] Jon Dron. *Control and Constraint in E-Learning: Choosing When to Choose*. Idea Group Publishing, 2007.
- [19] Emile Durkheim. *The division of labour in society*. New York: Free Press, 1997.

- [20] Umberto Eco. *Semiotics and the philosophy of language*. Indiana University Press, 1984.
- [21] Umberto Eco, Marco Santambrogio, and Patrizia Violi, editors. *Meaning and Mental Representations*. Indiana University Press, 1988.
- [22] Ronald Fagin, Joseph Y. Halpern, Yoram Moses, and Moshe Y. Vardi. *Reasoning about knowledge*. MIT Press, 1995.
- [23] Stephen Gourlay. The seci model of knowledge creation: some empirical shortcomings. In *4th European Conference on Knowledge Management*, 2003. <http://eprints.kingston.ac.uk/2291/1/Gourlay%202004%20SECI.pdf>.
- [24] Regine Hampel and Mirjam Hauck. Computer-mediated language learning: Making meaning in multimodal virtual learning spaces. *JALT-CALL Journal*, 2(2):3–18, 2006.
- [25] Friedrich A. Hayek. The use of knowledge in society. *American Economic Review*, 35(4):519–30, 1945.
- [26] Bill Hillier. *Space is the Machine: A Configurational Theory of Architecture*. Cambridge University Press, 1999.
- [27] Bill Hillier and Julienne Hanson. *The Social Logic of Space*. Cambridge University Press, 1984.
- [28] Wayne Hodgins and Erik Duval *et al.* *IEEE Standard for Learning Object Metadata*. IEEE, 2002.
- [29] S. Holland, D.R. Morse, and H. Gedenryd. Direct combination: a new user interaction principle for mobile and ubiquitous hci. In *Proceedings Mobile HCI*, 2002.
- [30] AppJet Inc. <http://etherpad.com/>.
- [31] Google Inc. <http://www.google.com/sidewiki>.
- [32] Yahoo! Inc. <http://delicious.com/>.
- [33] Angela Jones. Musical apocalypse: Tom waits' bone machine. *Forum*, 5, 2007.
- [34] Rick Kazman and Hong mei Chen. The metropolis model: a new logic for development of crowdsourced systems. *Communications of the ACM*, 52(7):76–84, 2009.
- [35] G Kress. *Literacy in the new media age*. London: Routledge, 2003.
- [36] Markus Krötzsch and *et al.* Denny Vrandecic. <http://semantic-mediawiki.org/>.
- [37] Marvin Levine. *Effective Problem Solving*. Prentice Hall, 1993.
- [38] Marshall McLuhan and Bruce R. Powers. *The Global Village*. Oxford University Press, 1989.
- [39] Marvin Minsky. *The Society of Mind*. New York: Simon and Schuster, 1988.
- [40] Felix Mödritscher, , Fridolin Wild, and Zinayida Petrushyna. Strategies and facilities for activity pattern sharing. Technical report, ROLE project, 2010. [https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38494498/D7.2%3a%20Strategies%20and%20Facilities%20for%20Activity%20Pattern%20Sharing%20\(PDF,%20final%20version\).pdf](https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38494498/D7.2%3a%20Strategies%20and%20Facilities%20for%20Activity%20Pattern%20Sharing%20(PDF,%20final%20version).pdf).
- [41] Felix Mödritscher and Zinayida Petrushyna. Model and methodology for ple-based collaboration in learning ecologies. Technical report, ROLE project, 2009. [https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38422819/ROLE%20Deliverable%20D7.1%7cID7.2%20\(final%20version\).pdf](https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38422819/ROLE%20Deliverable%20D7.1%7cID7.2%20(final%20version).pdf).

- [42] Kitaro Nishida. *Hataraku mono kara miru mono e*. Tokyo: Iwanami Shoten, 1927. Known in English as “From Acting to Seeing” or “From That Which Acts to That Which Sees”.
- [43] I. Nonaka and R. Toyama. The knowledge-creating theory revisited: knowledge creation as a synthesizing process. *Knowledge Management Research & Practice*, 1(1):2–10, 2003.
- [44] Brook Novak. <http://seaweed-editor.com/>.
- [45] Alexandra Okada, Simon Buckingham Shum, and Tony Sherborne. *Knowledge Cartography: Software Tools and Mapping Techniques*. Springer, 2008.
- [46] D. D. Olds. The behavioral schema: an integration of modes of learning. *Psychiatry*, 50(2):112–125, 1987.
- [47] Matthias Palmer, Erix Isaksson, and Ambjörn Naeve. Personal learning service bundles. Technical report, ROLE project, 2010. [https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38493013/D4.1\\_M12\\_final2.pdf](https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38493013/D4.1_M12_final2.pdf).
- [48] Matthias Palmer, Mikael Nilsson, and Ambjörn Naeve. Guidelines for the choice of integration technologies. Technical report, ROLE project, 2009. [https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38452279/D3.2\\_final.pdf](https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38452279/D3.2_final.pdf).
- [49] Dan Phiffer and Mushon Zer-Aviv. <http://www.shiftspace.org/>.
- [50] Steven Pinker. *The Stuff of Thought: Language As a Window Into Human Nature*. Viking, 2007.
- [51] Peter L. T. Pirolli. *Information Foraging Theory: Adaptive Interaction with Information*. Oxford Series in Human-Technology Interaction. Oxford University Press, 2007.
- [52] George Pólya. *How to Solve It*. Princeton University Press, 1945.
- [53] D.W. Shaffer, D. Hatfield, G.N. Svarovsky, P. Nash, A. Nulty, E. Bagley, K. Frank, A.A. Rupp, and R. Mislevy. Epistemic network analysis: A prototype for 21st century assessment of learning. *International Journal of Learning and Media*, 1(2):33–53, 2009.
- [54] Richard Stallman and Joshua Gay. *Free Software, Free Society: Selected Essays of Richard M. Stallman*. GNU press, 2002.
- [55] George Steiner. *After Babel: Aspects of language and translation*. Oxford University Press, 1975.
- [56] Mark Steyvers and Joshua B. Tenenbaum. The large-scale structure of semantic networks: Statistical analyses and a model of semantic growth. *Cognitive Science*, 29(1):41–78, 2005.
- [57] Chao Boon Kheng Leng Teo and Robert Gay. Concept map provision for e-learning. *Int. J. Instructional Technology Distance Learning*, 3(7):17–32, 2006. [http://www.itdl.org/Journal/Jul\\_06/article02.htm](http://www.itdl.org/Journal/Jul_06/article02.htm).
- [58] Katrien Verbert, Sten Govaerts, and Erik Duval. Version 1 of the role specifications. Technical report, ROLE project, 2010. [https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38484303/ROLE.D3.3\\_final.pdf](https://fit-bscw.fit.fraunhofer.de/bscw/bscw.cgi/d38484303/ROLE.D3.3_final.pdf).
- [59] Fridolin Wild and Laurian Gridinoc. <https://wiki.mozilla.org/Education/Projects/JetpackForLearning/Profiles/MUPPLE>.
- [60] C. Zinn. Bootstrapping a semantic wiki application for learning mathematics. In S. Schaffert and Y. Sure, editors, *Semantic Systems. From Visions to Applications Proc. of the*

*Semantics 2006 Conference*, pages  
255–260. Austrian Computer Society,  
2006.