Learning Through Design: Observations from a Constructionist Perspective on a (Possible) Paradigm Shift in the Field

by
Idit Harel
MIT Media Laboratory
Cambridge, Massachusetts
USA

Paper Presentation
The 5th International Logo Conference
Costa Rica, November, 1991

The research reported here was supported financially by: The IBM Corporation (Grant # OSP95952); The National Science Foundation (Grant # 851031-0195, and MDR 8751190); The McArthur Foundation (Grant # 874304); The Apple Computer Inc.; The LEGO Systems A/S; and Nintendo Japan Corp.

I thank Yasmin Kafai, Seymour Papert, Mitchel Resnick, Ricki Goldman Segall, and Uri Wilensky for their helpful comments on the transcript of my AERA-91 talk, and their contributions to my process of transforming my impressions from AERA-91 into this paper for the 5th International Logo Conference.

Learning Through Design: Observations from a Constructionist Perspective on a (Possible) Paradigm Shift in the Field

ABSTRACT

In this paper I argue that learning through design is a method of empowering learners and researchers of learning. I begin with a brief review of the "teaching thinking" paradigm which was dominant among researchers of educational computing in the '80s. A claim is made that the current research scene, within the same community, can be marked by a trend or a "paradigm shift" from "teaching thinking" towards a holistic and integrative "design paradigm" in both practice and research.

If this is true, with the emergence of this trend in the field, several questions for further research need to be considered: Are all the design projects which are described here the "same"? Can they all be considered Constructionist? In what ways are they different? What is the difference between Logo programming for the sake of programming (i.e., in isolation) vs. programming for the sake of producing educational software or games (i.e., in integration with other content areas)? Can people—young and old—really learn through design? What implications has this paradigm for educational researchers?

I do not attempt to provide answers to the many questions raised here, nor to fully explain this paradigm shift. The literature is reviewed quite superficially. However, I try to point it out and to describe some of the reasons for why integrative learning through design, and the process of producing of "real" computational products, can be more effective than simply programming short Logo programs in isolation from a larger and more complex goal. Previous implementions of the "design paradigm" with children in realistic school situations—in my own research and that of others at the MIT Epistemology & Learning Group—provide model cases. These reveal the merits of complex design and production processes as vehicles for learning: for helping students find relevancy in the domains being learned, and for encouraging their motivation, action, appropriation, comprehension, and reflection.

Integrating the Paradigm of "Learning through Design" into the Culture of Schools

This paper focuses on a Constructionist[1] paradigm of learning and of computer work with children which differs from traditional use of computer software (and of Logo programming) in schools in several ways. We have been calling this constructionist paradigm: "Learning by Designing," or "Design for Learning." It marks the difference, for example, between programming for the sake of programming (i.e., in isolation) vs. programming for the sake of producing interactive stories, educational software, or mathematical games (i.e., in integration with other content areas). Integrative learning through design, and the process of producing of "real" computational products, is seen as different than simply programming short Logo programs in isolation from a larger and more complex goal.[2] During the past six years, at the Epistemology & Learning Group at MIT, we have been conducting several "formal" experiments and many such "informal" projects on learning through design, by using the Logo programming language and the LEGO/Logo environments, among others.[3]

Integrating the paradigm of learning through design into the culture of schools is a research area now beginning to emerge in several research centers in the United States. One example supporting this claim comes from the last Annual Meeting of the American Educational Research Association (AERA, April 1991) in Chicago. I was struck by how

---

1 See Papert's writings about what characterizes Constructionism:
- Papert, S. (1986). *Constructionism: A New Opportunity for Elementary Science Education.* A proposal to NSF. Cambridge, MA: MIT Media Laboratory.
- Papert S. (1990). Introduction. In I. Harel (Ed.), *Constructionist Learning*. Cambridge, MA: MIT Media Laboratory.
- Papert, S. (1991). Situating Constructionism. In I. Harel, & S. Papert (Eds.), *Constructionism.* Norwood, NJ: Ablex (Chapter 1).

2 For richer conceptualization of "design for learning" in the constructionist framework, see:
- Harel, I. (1988). *Software Design For Learning: Children Construction of Meanings for Fractions and Logo Programming*. Unpublished Doctoral Dissertation. Cambridge, MA: MIT Media Laboratory.
- Harel, I. (1990). Children as Software Designers: A Constructionist Approach for Learning Mathematics. In *Journal of Mathematical Behavior, Vol. 9* (1) pp. 1-95. Norwood, NJ: Ablex.
- Harel, I., & Papert, S. (1990). Software Design as a Learning Environment. In *Interactive Learning Environments, Vol. 1* (1) pp. 1-32. Norwood, NJ: Ablex.
- Harel, I (1991). *Children Designers: Interdisciplinary Constructions for Learning and Knowing Mathematics in a Computer-Rich School.* Norwood, NJ: Ablex.
- Kafai, Y. (in progress). *Design for Learning: A critical Exploration of Theories of Design and their Educational Implications.* Unpublished Qualifying Paper. Cambridge, MA: Harvard Graduate School of Education.

3 For a complete list of design projects references, see the bibliography list in the Appendix of this paper.

much more sympathetic the AERA atmosphere was to this kind of work. In other words, my informal "ethnographic survey" of researchers and presentations during the 1991 AERA leads to identifying trends towards several of the themes which are central to the E&L work mentioned above (i.e., in footnotes 1, 2, and 3): the general constructionist approach to learning; the particular emphasis on design; the casting of children in the role of designers and media producers rather than consumers; and the enthusiasm towards—and multiple representations of—students' own computational products.

Later in this paper, I list several brief examples which may help us situate the "design paradigm" in the current research scene inside and outside the Logo community. But before I summarize my impressions of the current research scene, and before I present my claim about a possible "paradigm shift," a brief recapitulation of the relevant history of research in the field is necessary.

From "Teaching Thinking" to "Learning by Design"

In the mid-80's, precisely-defined studies on cognitive skills, their acquisition and performance in children and experts, within the paradigms of the "teaching of thinking," "studies in metacognition," "problem-solving skills" and alike, were most dominant in the field.[4] It was particularly true within the mathematics and science education research, the technology and education research, the framework of artificial intelligence in education, and the experimental studies of computer programmers.[5] Even Perkins' conceptualization of the "Knowledge as Design" theory back in 1985-1986 was conceived primarily within the framework of "teaching thinking." The act of constructive learning through designing and producing[6] was secondary. For Perkins, "thinking about knowledge and information as designs" represented an effective strategy for thinking, rather than for learners doing

---

[4] For example, Resnick, L., (1987). *Education and Learning to Think.* Washington DC: National Academy Press; and the literature review in Harel, 1988, and 1991.

[5] For representative examples of this paradigm, see the work reported in the following publications:
• Chipman, S. F., Segal, J. W. & Glaser, R. (Eds.) (1985). *Thinking and Learning Skills. Vol. 1 & 2.* Hillsdale, NJ: Erlbaum.
• Collins, A. & Brown, J. S. (1985). *The Computer as a Tool for Learning through Reflection.* Paper presented at the AERA Annual Meeting, Washington, D.C.
• Nickerson, R. S., Perkins, D. N. & Smith, E. E. (1985). *The Teaching of Thinking.* Hillsdale, NJ: Erlbaum.
• Soloway, E. & Iyengar, S. (Eds.) (1986). *Empirical Studies of Programmers.* Norwood, NJ: Ablex.

[6] In the ways expressed, for example, in Papert's vision and writings during the '80s, and prior to that.

(building) actual educational artifacts. His studies on Logo programming are examples of that methodology.[7] Most researchers in the Logo community shared this "teaching thinking" approach as well.[8]

These days, however, one can notice the emergence of an interesting trend, or even a *paradigm shift,* in both methods of research and educational practice within the same community of researchers. And as stated previously, several presentations during the 1991 AERA Annual Meeting provided some evidence of this paradigm shift. And while I am not really sure where it leads, I find it important enough to describe and raise some related questions.

Situating the Shift Towards the "Design Paradigm" in the Current Research Scene

Five years ago, Elliot Soloway, then at Yale University, invested most of his efforts in developing various programming and debugging tools, and in investigating the learning (and instruction) of programming from the point of view of helping students develop planning and debugging skills. He also investigated how expertise is attained by moving from problems to goals - to plans - to implementation in "an expert's style." In the past two years, with his colleagues at the University of Michigan, Soloway has investigated and developed tools for supporting learning through design. Their research projects with MediaText in the context of high-school classrooms are good examples of this current, very different, research enterprise.[9] Roy Pea, who in the mid-80's was known for his Bank Street studies on planning, debugging skills, problem solving, and cognitive transfer from Logo programming and other tools—started to run a multimedia production club for

[7] Examples of Perkins' early research on programming:
- Perkins, D. N. (1985). The Fingertip Effect: How Information Processing Technology Changes Thinking. In *Educational Researcher, Vol. 14* (7) pp. 11-17.
- Perkins, D. N. & Martin, F. (1985). *Fragile Knowledge and Neglected Strategies in Novice Programmers.* Technical Report no. 85-22. Cambridge, MA: HGSE, ETC.

[8] See, for example, the Conference Proceedings Books of *Logo '84, Logo '85*, and *Logo '86*, available from MIT; and many chapters in Pea, R. D. & Sheingold, K. (1987). *Mirrors of Mind: Patterns of Experience in Educational Computing*. Norwood, NJ: Ablex.

[9] a) *HyperText Environments Expand the Bandwidth of Interactivity;* b) *The Promise of Technology for Promoting Change;* and c) *MediaText Demonstration*. Elliot Soloway, Advanced Technology Center, University of Michigan. All three papers were presented at the Annual Meeting of the AERA, April 1991, Chicago IL. Compare these to his past studies in Soloway E. & Iyengar, S. (Eds.) (1986). *Empirical Studies of Programmers*. Norwood, NJ: Ablex.

children's learning in January of 1991. This rich design-based learning environment plays an important role in Pea's current research. It is epistemologically different from the kinds of environments he chose to study in the past.[10] During 1986-88, at Carnegie-Mellon University (CMU), Sharon Carver studied debugging abilities and Logo programming misconceptions in children, and came up with a set of well-defined instructional strategies to foster and strengthen debugging and problem-solving in children's programming. Today, at the University of Rochester, Carver designs learning environments of a very different kind: students learn problem-solving through their design and production of HyperCard-based software.[11] In Richard Lehrer's recent studies at the University of Wisconsin-Madison,[12] we see students learning about historical topics, such as the Civil War, by designing software about the Civil War for other students in the school. Lehrer has also recently adopted a design approach, which he did not use in his Logo studies of the 80's. Likewise, Bill Tally and Kathy Wilson from Bank Street College recently entered a new phase in their work. Wilson, a multimedia designer of sophisticated instructional materials for schools and museums, is now passing the authorship power to the hands of her NYC students.[13] Ann Brown and Michael Jay at UC-Berkeley also use HyperCard-based tools to study children's design and production process, and social construction of knowledge in their Scientific Literacy Project.[14] At OISE Canada, to take another example, Marlene Scardamalia[15] and her colleagues have been developing computer

---

[10] See, *Students Learning through Design with Multimedia Tools for Collaborative Research, Composition, and Presentation.* Pea, R. D., Allen C., Chertok, M., Godreau, E., Shaw, J., & Velrum, N. Institute for Research on Learning (IRL). Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL. See also, Learning with Multimedia. In *IEEE Computer Graphics & Applications,* July 1991 Issue, pp. 58-66. (Compare this work to earlier Logo studies by Pea and his colleagues, in Pea R. D., & Sheingold, K. (1987) *Mirrors of Mind.* Ablex.)

[11] See, *Interdisciplinary Problem Solving.* Sharon Carver, University of Rochester. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL. (Compare that to Carver, 1986, *Transfer of Logo Debugging Skills: Analysis, Instruction, and Assessment.* Unpublished Ph.D. Thesis, Pitsburgh, PA: Carnegie-Mellon University.)

[12] See, *Knowledge Design in History.* Richard Lehrer, University of Wisconsin-Madison. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL. (Compare to Lehrer, 1988, *Developing Learning Performance in Geometry with Logo.* Paper presented at the NCTM Annual Meeting, Chicago.)

[13] See, *Multimedia Authorship in the Classroom.* Bill Tally and Kathy Wilson, CCT, Bank Street College. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL.

[14] See, *The Scientific Literacy Project.* Ann Brown and Michael Jay, UC-Berkeley. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL.

[15] See, *Computer Environment for Group-Based Knowledge Construction: CSILE Computer Supported Intentional Learning Environments.* Marlene Scardamalia, OISE. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL. Scardamalia and her colleagues have been working in this framework

environments that support *children's design and construction* of scientific data bases. Andy diSessa, who, during the past 10 years, built some of the most exciting microworlds for learning with Logo, and later with Boxer, *for* children, is now beginning to implement Boxer in classrooms in a slightly different way—as a design learning environment for children. The students who diSessa is currently working with are beginning to use Boxer for representing their knowledge and arguing with other students about it.[16] The image of the "child as a designer" is so dominant in his current work, and, in the near future, we may be able to see studies of *children* designing and programming microworlds for physics and mathematics similar to the ones that diSessa once constructed for them.

There are several other holistic projects in the spirit of the design paradigm that are beginning to emerge in the field. The ACOT Projects (Apple Classrooms of Tomorrow) is another larger example. ACOT began its operations about four years ago by placing many computers and ready-made software for children to use. Their initial reports were about various ways of existing software-use in computer-rich classrooms. However, some of their current reports[17] indicate that in some ACOT classrooms, they begin to observe how students learn by building their own software and expert systems for their classes, their schools, and their larger community.

As a side note, with the emergence of these holistic, "messy," design-based projects on thinking and learning, several papers at AERA explicitly reflected the need for a shift in research methodology. These reflected current changes in the *kinds of learning and thinking situations researchers choose to design, experiment with, and study.* Edith Ackermann, for example, presented how clinical interviews in the Piagetian spirit can be stretched to become design environments for learning—for both the researchers and their

---

for the past three years. Therefore, this is not a clearcut example of a paradigm shift in their work. Yet, they now choose to emphasize certain aspects of "learners as designers and builders" in ways not explicitly expressed in previous years.

16 Personal communication; and his paper, *Images of Learning*. Andrea diSessa, UC-Berkeley. diSessa's vision and writings in the past 10 years have been promoting the image of the "child as designer." However, it is only recently that we can see these visions actually implemented in the studies conducted by him and his research team at Berkeley. See, for example, diSessa, A., Hammer, D., Sherin, B., & Kolpakowski, T. (in press). Inventing Graphing: Children's Meta Representational Expertise. *Journal of Mathematical Behavior.*

17 See, *Trading Places: When Teachers Utilize Student Expertise in Technology-Intensive Classrooms.* Judith Haymore Sandholtz, Cathy Ringstaff, and David Dwyer, Apple Computer, Inc. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL.

subjects.[18] In the talk for the Award for Distinguished Contributions to Educational Research, Lauren Resnick provided her fascinating personal accounts about this shift in methodology from 1985 to 1990, and how this shift expressed itself in her own research, theorizing, and writing about the learning and thinking situations she chose to investigate in the laboratory or implement in educational settings.[19] And Ann Brown gave an explicit talk about the current need to shift in methodologies, and reflected on changes in the kinds of environments she currently designs and studies.[20]

It is far beyond the scope of this paper to deeply investigate the reasons for shifts in research methodology. However, the point I wish to make here is that research enterprises and educational projects of the kind listed above did not (widely and explicitly) exist before. Research on students' learning through complex, integrative, and messy design projects did not exist much in the literature, or even in the air.[21]

As researchers we need to ask ourselves: Why now? What does all this mean?

It seems as if the design paradigm of computer-based activity in schools is emerging in many places and multiple forms now. Without denying the fact that certain technologies

---

[18] See, *Who is Designing What for Whom, and Who is Learning What from Whom?* Edith Ackermann, MIT Media Laboratory. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL. (For Ackermann, however, this paper does *not* represent a current shift in research methodology. She has been writing and researching in this spirit for the past 10 years.

[19] See, *Situations for Learning and Thinking.* Lauren Resnick, University of Pittsburg, Learning Research and Development Center (LRDC). Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL (as the Award for Distinguished Contributions to Educational Research-1990). Compare that to *Education and Learning to Think.* Washington DC: National Academy Press (1987).

[20] See, *On Paradigms and Methods: What Do You Do When the Ones You Know Don't Do What You Want Them To?* Ann Brown, UC-Berkeley. Paper presented at the Annual Meeting of the AERA, April 1991, Chicago IL (in a session with Allan Schoenfeld from UC-Berkeley, and Geoffery Saxe from UCLA).

[21] Only to a certain extent they were "in the air" at MIT of 1985: in Papert's vision, and in some of his writings, as well as in Jeanne Bamberger's and Donald Schon's work. But even within the MIT Logo community, there was a strong need to develop the idea of constructionist learning further and in richer ways (e.g., Papert, 1986; 1987), and to develop methods for building even stronger models (or cases) in educational practice for "Constructionism" and for "Design for Learning." Today we have accumulated a large collection of cases to support this paradigm from a variety of perspectives. See in I. Harel & S. Papert (Eds.) (1991) *Constructionism.* Norwood, NJ: Ablex.

give rise to certain research and educational practice activities not possible before,[22] my assumption is that *researchers and their theoretical frameworks* changed, and not only the technological developments. We must try to understand this process:

- What is this trend about?
- What factors in our intellectual "fashion" could explain this trend?
- What factors in our society could explain this trend?
- Can we see it happening in other areas? Which ones?

Another set of questions can focus on a much closer and deeper analysis of the research projects mentioned above:

- How close are these projects to the Constructionist end of things?
- In what ways are they similar or different?
- What factors in research and educational practice contributed to these researchers' shift in paradigms?
- What technological/computational factors contributed to this trend?

Some Speculations on the Merits of the "Design Paradigm"

In order to begin to understand the design paradigm, let me specify five reasons for why I think "learners as designers" (or "design for learning") is a rich paradigm for children's learning and for research on learning, and in what ways it is different from other educational approaches. My speculations or "reasons" are, first and foremost, based on a long process of gradual accumulation of results from many experiments and projects, conducted by myself and my colleagues at the Media Laboratory; as well as on relevant theory building by Papert, Perkins, Schon, Ackermann, and Shannon—among others. Because the following reasons are interrelated and overlap each other in many ways, it is not natural to list them separately in the way I do here for the purpose of this paper. The integration of these reasons in one learning-research enterprise is the important point I would like to make here.

---

[22] For example, technological developments such as car-phones, word processors, fax machines, Macintosh, LogoWriter programming, object-oriented programming, parallel-processing programming, etc. However, see Falbel, 1991 for his elaboration of Papert's argument from *Mindstorms* (1980)—that good wood doesn't produce good houses. People do. Moreover, as researchers and educators we must remember that even the most powerful and flexible technology has the potential of being used in ways that limit children's thinking and learning power (Papert, 1987, 1991).

First Reason. **Design motivates learning.** Before any learning and productive thinking can occur, people must be motivated. Motivation to learn and think depends on recognizing that something is important, that it is relevant to oneself. Recognizing relevance and the ability to appropriate knowledge depends on cultural background and self awareness.[23]

The Epistemology & Learning Group conducts many studies at an inner-city elementary school in Boston. What we see is that many young inner-city people in our age of cultural pluralism and socio-economic inequities have problems getting to know who they are, what is relevant for their lives, why mathematics, and why education (in the ways presented in "typical" American schools) is important and relevant to them. Our present educational system unfortunately offers little help in evoking relevancy, in connecting the learners' outside-of-school cultures with their inside-of-school cultures and in making education meaningful for students. Design-based learning can do it. It must be the productive work of the knowing self.[24] Constructionist design activities can encourage motivation and bring learners to find the relevancy of the domain learned.

A great deal of research within the Epistemology & Learning Group explores the ways in which design-based activities can make education more relevant for students. In various projects involving Logo programming and LEGO/Logo, we have been observing how, learners generate concepts, explore ideas, construct products, and appropriate ideas in different voices and in personal ways.[25] We found that certain design activities allow learners to find relevancy and are excellent vehicles for fostering motivation.

For example, in a series of research projects called ISDP,[26] the act of making a software product for a real user seemed to motivate students for quite a long period of involvement (i.e., four months) with one particular project. One of the most solidly documented findings of ISDP work is the importance of the long time frame in learners'

---

[23] Shannon (1990, p. 39) discussed the idea of finding relevance through design in Toward a rationale for public design education. In *Design Issues, Vol. 7* (1), pp. 29-41. The MIT Press; Papert elaborates the idea of appropriating knowledge and making it one's own through the process of making, designing, and building things is in all of his writings of the last decade.

[24] See Shannon (1990), pp. 40-41. See also Perkins on design and "active knowledge" in *Knowledge as Design*, p. xiii, Hillsdale, NJ: Erlbaum (1986).

[25] Turkle & Papert, 1990; 1991; Harel & Papert, 1990; Resnick & Ocko, 1991; Resnick, 1991; (the complete references and other related ones can be found in the Appendix of this paper).

[26] Harel, 1988; 1990; 1991; Kafai & Harel, 1990; (complete references in the Appendix).

process of appropriation of ideas, and in learners' ways of making these complex ideas relevant to themselves. For example, several of the children who showed the greatest gains from the software design experience took several days—sometimes even several weeks—to find a voice in which they were comfortably able to engage the subject matter—i.e., rational-number concepts. We have also documented that the awareness of an 'end user' in the process of learning made a significant difference in the students' motivation for learning and their engagement with fractions (also discussed in the fourth reason below).

The "production process" in ISDP initiates a cycle that begins with the forming of self awareness: From the very beginning of the project, the young software designers need to face serious questions,

What do I know about fractions?

Why do I care about fractions?

What do I want to explore within this domain?

What do I want to communicate and represent for other students?

How am I going to do it?

When students ask themselves such crucial questions in their process of learning, these questions are leading them to the perceiving of relevance,[27] and especially, to becoming motivated. This leads to professional engagement in the mathematical learning process – and cycling again, to a further and stronger sense of taking a stance, and announcing to the world: *'This is what I think about fractions; these were my problems with fractions; this is how I figured it out; this is how I programmed it; and all of that is embedded in my design.'*

As researchers we are interested in investigating what are the gains of such a process. We assess the ways in which design offers students an active and meaningful role in their process of learning.

Second Reason. **Designers make things happen.** Design substantiates learning in actual accomplishments.[28] For reasons described above, in ISDP (which was a mathematical design project), for example, students learn first hand that knowing mathematics does not "just happen." They do mathematics, they design representations, and they make it happen. They do this in the form of creating instructional mathematical

---

[27] Perkins (1986) describes these questioning process as an "active process of asking design questions" in *Knowledge as Design*, pp. 94-122.

[28] See Shannon, (1990, p. 40); and see Perkins (1986) discussion of learning by "accomplishing products rather than short answers" (p. 215) and "making knowledge functional" through design (p. 217).

representations for fractions—creating fractions software, individually and collaboratively—on their computers. Passive learning and voyeurism can hardly exist in such an environment.[29]

Third Reason. **Designers make personal connections between the affective and the cognitive. It is putting people, feelings, things and situations together.**[30] In ISDP, for example, this point expressed itself in the extent to which students responded to a problem about fractions by digging around in their personal stocks of knowledge and feelings towards fractions; and even through their decisions about the color of shapes, or the size, or the number of the fractions on a computer screen, as well as in choosing what style of representation is appropriate for what concept they wanted to communicate. This is an example for when designing can be an educational process that can lead learners towards a productive and a personal (affective and cognitive) contribution to their learning environment. Resnick too, has documented similar findings in children and adults working in LEGO/Logo environments.[31]

Fourth Reason. **Designing a product promotes consideration of intended users.** Designers learn by communicating something to their community. The difference between simply doing something and designing a real product is in the level and quality of commitment and consideration given to the task, and in how one feels while accomplishing it.[32] Too often in schools, it is possible to do things mindlessly while acting as agents for someone else (usually the teacher). Even with high performance, there may be no sense of reward in finishing the job. We found, for example, that designing software or LEGO/Logo constructs cannot be automatic and mindless. It forces critical thinking, personal judgement, and deep involvement. Our observations of young software designers

---

[29] See Harel, 1988; 1990; 1991; and Kafai & Harel, 1991a; 1991b; (complete references in the Appendix).

[30] Harel & Papert, 1990 on the ways affect affects learning, pp. 22-23; and Shannon, 1990, p. 40.

[31] Resnick & Ocko, 1991; Resnick, 1991 (complete references in the Appendix).

[32] Shannon (1990, p. 40-41) also expresses the idea that design forces the consideration of the community of others that designers serve, and therefore, makes the process of design meaningful to the designer; Perkins (1986, pp. 215-216) discusses the difference between considering target performances (in traditional schooling) vs. considering target products for a particular purpose (in design learning process).
Also, this same idea in relation to learning music through design of musical products appears in Gargarian, G. (1991). Towards a Constructionist Musicology. In I. Harel & S. Papert (Eds.), *Constructionism*. Norwood, NJ: Ablex (Chapter 16).

in ISDP and of students building with LEGO/Logo tell us that good designing for other students always evokes feelings of pride and accomplishment.

In addition, "learning by teaching" in design environments is presented in the context of ISDP as a related principle.[33] In this, we turn the usual tables by giving the learner the active position of the teacher/explainer rather than passive recipient of knowledge. We also give the learner the position of designer/producer rather than consumer of software. It is a new elaboration of the old idea of learning by doing rather than by being told.[34]

Fifth Reason. **Design is integrative and holistic.** Implementing design activities in the school environment can provide an interesting marriage of the "everyday," "real-world" type of activities and the "formal," "school-like" type of activities.[35] The idea of "designing for learning" as an integrative human capability has been subordinated in our culture in general, and certainly, not valued enough in the culture of our schools. Design activities are not usually integrated into the study of mathematics. Rather, they are left for art classes, woodworking workshops, etc. There is a need to take advantage of the transdisciplinary and comprehensive nature of any design process, and to explicitly include it into the larger context of human development and schooling.[36] This is because designing has significance beyond the architecting of buildings and the making of enjoyable and effective environments. It is not just another skill we need to learn in school so we can use it when we grow up, to make our society's industry profitable (a common argument among some people who wish to bring design education into schools). Rather, design is viewed here as an **empowering principle,** as a discipline which facilitates other learning, and which marries cultural background, school activities, thought, action, creativity, construction, and reflection.

In this sense, ISDP is also a model of holistic and comprehensive learning through design, giving students exciting evidence for how their mathematical school work relates to them, to their lives, and to their community—inside and outside of school. Students can learn to integrate ideas: they experience how math relates to language, how learning relates

---

33 Harel, 1991; Kafai & Harel, 1991a; (complete references in the Appendix).

34 Or what Papert describes as "Constructionism" rather than "Instructionism." See Papert, 1990; 1991.

35 Perkins (1986, pp. 224-225) describes this aspect of design as the "bridging from context to context" and "crossbreeding subjects areas."

36 See Perkins, 1986, p. xvi, 224, 225; Shannon, 1990, p. 41; and in many places throughout Schon, D. (1987) *Educating the Reflective Practitioner.* San Francisco, CA: Jossey-Bass.

to teaching, how art relates to science, and how communication relates to understanding. By testing their software (while it is under construction) with third-grade children (who serve as "test subjects"), they can also relate concepts and skills of a different domain of knowledge—namely, the technologically-oriented domains of product design, implementation, and testing. Moreover, by designing software for fractions they are certainly engaged with mathematical ideas and their representations; but they are no less engaged with expression of ideas in words (in writing and reading), in pictures (in art), and in moving images (in animation). They are also engaged in thinking about teaching—a subject which touches on the lives of children in very personal ways, and in thinking about design—a subject that is rarely implemented in schools, and almost never integrated with mathematics learning. Thus, ISDP is oriented to connect with other subject areas and skills. In this way, the design process lends itself particularly well to the "whole learning" analogous to the concept of "whole language" that has achieved currency among many educators in the past few years.[37]

Summary

"Constructionist Learning" and "Design for Learning," in the ways I only began to illustrate here, are examples of paradigms for empowering children. The researchers and educators who design environments and technology with this framework in mind (with and without advanced technology) are empowering learners. The above five reasons for design as an effective learning principle can only provide partial explanations for the shift towards the "design paradigm" in the current scene of learning research, and of educational computing in particular. Nevertheless, there is a clear need for a better conceptualization of what "design," or "the child as a designer" could mean in the different studies I listed above and in educational practice, and what will be the implications of these images and experiments on theory and research about thinking and learning.[38] There is also a need to refine and better define this shift in paradigms, and to implement and compare different learning environments and research enterprises of this kind.

---

[37] On the Whole Language approach, see for example, Holdaway, D. (1979). *The Foundations of Literacy.* Sydney, Australia: Ashton Scholastic.

[38] In her recent paper, Kafai focuses on these very issues. See, Kafai, Y. (in progress). *Design for Learning: A critical Exploration of Theories of Design and their Educational Implications.* Unpublished Qualifying Paper. Cambridge, MA: Harvard Graduate School of Education.

Appendix / Bibliography

The following is a brief summary of "children as media designers" research projects during the past 6 years within the Epistemology & Learning Group at the MIT Media Laboratory:

• FIRST STUDY: "Children as Fractions Designers," Harel, 1986
(Pilot Study)
- The project lasted 1 month with 18 fifth-grade students.
Five participants were studied in depth after the completion of the project. The children were from Linda Moriarty's and Joanne Ronkin's classes at Project Headlight.
The results of this study are available in:
• Harel, I. (1986). *Children as Software Designers: An Exploratory Study in Project Headlight.* Paper Presented at the LOGO-86 International Conference. Cambridge, MA: MIT Media Laboratory.

• SECOND ISDP STUDY: "Software Design for Learning," Harel, 1987-1988
(Dissertation Study)
- The project lasted 4 months in Linda Moriarty's classroom.
- 17 fourth-grade children participated in the Experimental class, and two other classes from the same school made the two Control Groups .
A description of this study and its results is available in:
• Harel, I. (1988). *Software Design For Learning: Children Construction of Meanings for Fractions and Logo Programming.* Unpublished Doctoral Dissertation. Cambridge, MA: MIT Media Laboratory.
• Harel, I. (1990). Children as Software Designers: A Constructionist Approach for Learning Mathematics. In *Journal of Mathematical Behavior, Vol. 9* (1). Norwood, NJ: Ablex.
• Harel, I., & Papert, S. (1990). Software Design as a Learning Environment. In *Interactive Learning Environments, Vol. 1* (1). Norwood, NJ: Ablex.

• THIRD & FOURTH ISDP STUDIES: Kafai & Harel, 1989-1990
(Two Re-Implementations of ISDP Studies)
- The two projects lasted a whole year with three teachers and their classes. Fifth graders designed software for fourth graders in the Fall. Fourth graders designed software for third graders in the Spring, and the fifth graders became software-design consultants.
The first implementation was in Marquita Minot's fifth-grade class with 15 students, lasted three months.
The second implementation was in Gwen Gibson's fourth-grade class with 21 students, lasted three months.
A description of this study is available in:
• Kafai, Y., & Harel, I. (1990). Replicating the Instructional Software Design Project: A Preliminary Research Report. In I. Harel (Ed.), *Constructionist Learning*. Cambridge MA: MIT Media Laboratory.
• Kafai, Y., & Harel, I. (1991a). Learning through Design and Teaching: Exploring Social and Collaborative Aspects of Constructionism. In Harel, I., & Papert, S., (Eds.). *Constructionism.* Ablex (Chapter 5).
• Kafai, Y., & Harel, I. (1991b). Children Learning through Consulting: When Mathematical Ideas, Knowledge of Programming and Design, and Playful Discourse are Intertwined. In Harel, I. & Papert, S. (Eds.) *Constructionism.* Ablex (Chapter 6).

• FIFTH ISDP STUDY: "Children as Game Designers," Yasmin Kafai, 1990-1991
(Dissertation Study)
- The project was conducting during Spring 1991, will last a whole semester within one fourth-grade class.
- We added a new context: instead of instructional software design, we are now asking the children to design educational mathematical games (i.e., software games for teaching fractions concepts for third graders).

- A description of this study will be available in Yasmin Kafai's Dissertation (Spring, 1992). See also,
Kafai, Y. (in progress). *Design for Learning: A critical Exploration of Theories of Design and their Educational Implications.* Unpublished Qualifying Paper. Cambridge, MA: Harvard Graduate School of Education.

• Other related research on constructionist learning by design from the Epistemology & Learning Group:

Papert, S. (1986). *Constructionism: A New Opportunity for Elementary Science Education.* A proposal to NSF. Cambridge, MA: MIT Media Lab.

Papert, S. (1990). Introduction to Constructionist Learning. In Harel, I. (ed.). *Constructionist Learning: A 5th Anniversary Collection.* Cambridge, MA: MIT Media Lab.

Papert, S. (1991a). Situating Constructionism: A Theoretical and Social Context. In Harel, I., & Papert, S. (Eds.). *Constructionism.* Norwood, NJ: Ablex (Chapter 1).

Turkle, S., & Papert, S. (1991). Epistemological Pluralism and the Revaluation of the Concrete. In Harel, I., & Papert, S. (Eds.) *Constructionism.* Norwood, NJ: Ablex (Chapter 9).

Resnick, M., Ocko, S., and Papert, S. (1988). LEGO, LOGO, and Design. In *Children's Environments Quarterly. Vol. 5* (4). New York, NY: Children's Environments Research Group, The City University of New York.

Resnick, M., & Ocko, S. (1991). LEGO/Logo: Learning Through and About Design. In Harel, I., & Papert, S. (Eds.) *Constructionism.* Ablex (Chapter 7).

Resnick, M. (1991). Xylophones, Hamsters, and Fireworks: The Role of Diversity in Constructionist Activities. In Harel, I. & Papert, S. (Eds.) *Constructionism.* Ablex (Chapter 8).

Falbel, A. (1991). The Computer as a Convivial Tool. In Harel, I. & Papert, S. (Eds.) *Constructionism.* Norwood, NJ: Ablex (Chapter 3).

Wilensky, U. (1991). Abstract Meditations on the Concrete and Concrete Implications for Mathematics Education. In Harel, I. & Papert, S. (Eds.) *Constructionism.* Norwood, NJ: Ablex (Chapter 10).

Gargarian, G. (1991). Towards a Constructionist Musicology. In Harel, I. & Papert, S. (Eds.) *Constructionism.* Ablex (Chapter 16).

Jackson, I. (1990). Children's Software Design as a Context for Studying Collaboration. In I. Harel (Ed.), *Constructionist Learning: A 5th Anniversary Collection.* Cambridge MA: MIT Media Laboratory.

Dickinson, S., & Schaffer, M. (1990). The Visual Telecommunication Workstation. In I. Harel (Ed.), *Constructionist Learning: A 5th Anniversary Collection.* Cambridge MA: MIT Media Laboratory.

Benenson, A. (1990). *VideoLogo: Synthetic Movies in a Learning Environment.* Unpublished Master's Thesis. Cambridge, MA: MIT Media Laboratory.

Harel, I. (1990, June). Expanding the Logo Environment: A Review of Research & Development Projects of Multimedia Programming Environments for Young Learners. In D. Newman (Ed.) *AI & Education SIG News Letter,* pp. 9-14. Based on a Paper presented at the AERA-90 Symposium entitled, "Computers and Learning: Human Construction and Artificial Intelligence."

Harel, I (1991). *Children Designers: Interdisciplinary Constructions for Learning and Knowing Mathematics in a Computer-Rich School.* Norwood, NJ: Ablex.