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Build, Launch, Convene: Sketches for Constructive-Dialogic Learning Environments

Edith Ackermann, Carol Strohecker

TR99-30 December 1999

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In PatternMagix, children play in a world of colorful tiles and geometric operations, from which they forge mosaic-like patterns. In AnimMagix, children create whimsical creatures and then launch them onto a field in which the creatures interact, affecting one another's behaviors. We have developed working prototypes of PatternMagix and AnimMagix, and here explain their operation and concordance with design principles that promote personally meaningful construction through conversational turn-taking.

Beyond the concerns of specific domains like geometric patterns and social transactions, we cast our applications in the realm of multivariate, dynamic systems. Consistent with the property of distributed control so important in this realm, each Magix microworld1 adapts a mode of presentation, gestural involvement, and emotional and cognitive engagement consistent with the constructive-dialogic style of interaction.

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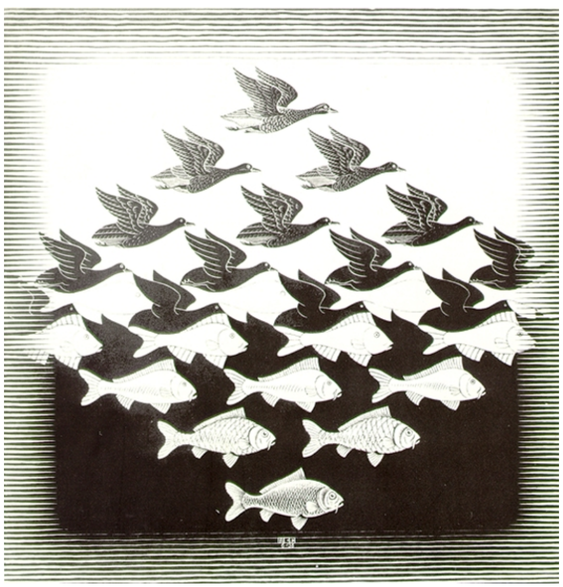

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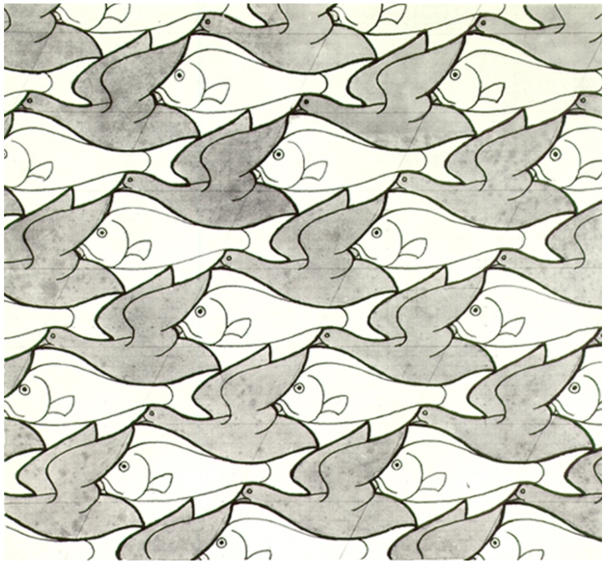

These evocative illustrations are from Locher, J. L. (ed.), The World of M. C. Escher. *Harry N. Abrams, Publishers, New York, pp. 105-106.*

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Introduction

People live in a world of complex social webs and intricate physical systems. In the course of normal growth, through interactions with their surroundings, children develop their own reliable intuitions about properties of multivariate, dynamic systems. From very young ages, children relate to and invent theories about these systems, including the properties of balance, equilibrium, feedback, and self-regulation [Piaget 1951, Ackermann 1991, Papert 1993, Montangero 1996]. These intuitions can support development of deeper, more principled understandings of complex, often counter-intuitive phenomena.

Magix environments can be seen as intuition builders. They support experimentation with and contemplation of emergent effects within dynamic systems. Through such explorations, learners can develop conceptual foundations for more formal study of the overarching mathematical and scientific principles.

Two main questions drive our inquiry: What is it that computers do particularly well, and which people would not do as well without them? In what ways can computers help us to simulate complex, dynamic phenomena, while remaining “convivial” partners for playful, exploratory learning [c.f., Illich 1971]?

Our approach emphasizes learning rather than teaching. The model is one of experimentation, distributed control, and conversational exchange rather than prescribed curriculum or unilateral control. Rather than imposing a sequence of activities or topics, the system responds to the learner’s interventions with specific, consistent, context-dependent functionality. This approach constitutes a model of partnership, which forms the basis of the interaction design for Magix learning environments.

Design Principles for the Magix Series

We work in the *constructionist* tradition, which holds that learning happens especially well when the learner is engaged in creating personally meaningful things that can be shared with others [Papert 1980, 1991]. In designing computational media as

partners for personalized, exploratory learning, we consider which aspects of the constructive process are best performed by the person and which can best be performed by the computational system. In addition to leveraging computational capabilities such as external memory and dynamism, our purpose is to allow for shared exploration, while leaving the creative part to the person.

Human learners are typically good at forming questions, making guesses, and forming scenarios. However, they can get stuck in a certain view or approach, neglecting alternatives that could prove fruitful. Computers generally are not very good at forming questions, but they can be programmed to generate variations and identify possible courses of action, given some set of conditions and constraints. With today's computational media we can also develop dynamic models and simulations, enabling exploration of multivariate changes as they play out over time. This capability enables us to grapple with processes may be too complex for the unaided mind to handle. Furthermore, unlike handwritten notations and graphs, digital modeling tools can transform their inputs. They carry out operations that could only be posited in traditional pencil-and-paper representations. Ironically, it is the digital tools' relative degree of autonomy that offers potentials for partnership.

Learning researchers note that people engaging in complex tasks often invent sophisticated ways of using available resources and distributing cognitive load. Indeed, researchers employ the same strategies, even as they struggle to understand them. They fabricate tools that learners can use in externalizing processes of thinking, making these processes available for study. Not surprisingly, the most daunting challenge in creating such tools is not technological, but has to do with researchers' still limited understandings of people's ways of thinking and learning.

Many of the tools available for the inquiry are based on the assumption that control is unilateral: either the learner controls the machine, or the machine controls the learner. The Logo programming language and many dynamic modeling tools are examples of the former, constituting an important view of learner-centeredness. Tutoring systems are an example of the latter: the old-style automated tutors purported to be interactive by providing students with opportunities to make choices, but the program of instruction was generally fixed, thereby restricting possibilities for learning in any deep sense. More recently, so-called "intelligent tutors" employ parameter settings and adaptive, behind-the-scenes filters that characterize users' interactions, thereby developing "user models" that help to create more personalized experiences [Sleeman and Brown 1981, Wenger 1988].

We find ourselves at an interesting middle ground with respect to these approaches. Acknowledging the great diversity in human learning and thinking styles [Turkle and Papert 1990], and asserting that "style" pertains to issues of control, we address potential benefits of situations in which learners can share control. Our design maintains the constructivist principles of people learning through building and individually selecting what they build, but also addresses *how* the building happens.

In our middle ground, we avoid turning the computational device into a “teacher” whose role is to tell the learner what to do or how to think. At the same time, we grant autonomy to the computer so that it can be engaging as a partner. We focus on the machine’s ability to simulate complex processes through dynamic modeling. Our Magix environments strike the balance by accepting inputs from the learner and allowing the system to transform them in intriguing, often surprising, ways.

Constructive-Dialogic Interaction

In their two volumes on *constructionism,* Papert et al. substantiate how the insights of Piaget, Dewey, Bruner, and Vygotsky can be combined with today's technological capabilities to extend the scope of Piagetian *constructivism* [Harel and Papert 1991, Kafai and Resnick 1996]. A key addition is the notion of learning as design – that is, the idea that learning "happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it’s a sand castle on the beach or a theory of the universe" [Harel and Papert 1991, p. 1]. In a process of construction, people project their ideas into an external, shareable object: the object comes to incorporate those ideas, in some sense. As the creator and other people use the object, its particular characteristics facilitate introjection: that is, the object helps to further shape the ideas. The artifact is thus an important kind of mediating device.

Our work extends the constructionist foundations to examine *how* people engage with objects to produce mediated constructions. We begin, consistent with Don Schön's coinage, by focusing on design as a "conversation" with artifacts [Schön 1983, 1992]. We have formulated a manner of design and construction based on conversational turn-taking within graphical software environments, and call this approach the *constructive-dialogic* style of interaction. This term reflects the premises that ideas can be made accessible through building, that building can happen through negotiational processes, and that the resulting objects can be shared. As Papert et al. have demonstrated, these processes of building-through-negotiation and sharing create optimal conditions for learning.

Cognitive theorists, including constructionists, address the importance of negotiation in establishing a distinction between two kinds of builders: *planners* and *bricoleurs* [Suchman 1983, Papert and Turkle 1990].

Planners know ahead of time what steps they will take in order to get something done. If they are chefs, they write a recipe and then follow it. If they are writers, they develop an outline and stick to it as they generate new text. In general, planners prefer to use materials and ingredients designated for a given task rather than improvising.

Bricoleurs, on the other hand, typically do not know ahead of time how they will go about doing something, and may not know what they will use in order to get the job done. If they are chefs, *bricoleurs* select from what is available, blending ingredients according to personal taste. *Bricoleur* writers tend to externalize a stream of consciousness or assemble existing passages, and then edit. In general, *bricoleurs* collect objects that seem interesting or potentially useful, and bring them into a situation as the need arises. Often, new goals emerge in the course of work: *bricoleurs* use unexpected side-effects as springboards for how to proceed. The process of building is guided by personal likes and dislikes, as well as by use of materials cleverly adapted for the task at hand. The construction becomes a montage of both process and product. *Bricoleurs* resemble good conversationalists, who even when encountering a stranger, manage to quickly find common ground and use it to further the conversation.

Constructive-dialogic interaction allows for the approaches of both planners and *bricoleurs,* but provides affordances that may be particularly appealing to the latter. It acknowledges the situated approach characteristic of *bricoleurs* as a way of developing useful, elegant results.

Moreover, adding conversational turn-taking to the building of personally meaningful products goes beyond the question of *how* the building happens, to *who* is doing the building [Bakhtin 1981, Wertsch 1991]. Bakhtin's great contribution, from a psychological perspective, is to remind us that a thinker, designer, or learner is never alone, but carries within a collection of voices reflecting the influences of others as well as the thinker's own ideas. The "voices" with whom a thinker or designer interacts may be of people present or absent at a given time, and these voices may be fictional rather than real [Strohecker 1999]. The attempt to create coherence among many voices is, for Bakhtin, at the core of human intelligence and forms the basis of both internal and external "worldmaking" [c.f., Goodman 1978]. Indeed, the process of creating coherence from multiple voices is the very process of making meaning. Hence interactions are like conversations, and they may be with oneself, another person (or persons), or a person's legacy as embodied in a tool, a toy, or a computational kit.

Conversation is an appropriate model for negotiation and partnership. When approaching and engaging with one another, conversationalists help each other to answer basic questions: Who are you? What is it about you that I already know and can understand or relate to? Where is the common ground in our interests? How can we be useful to one another? In exchanging varying forms of such implicit questions, conversationalists learn not just the answers, but also how to proceed with the conversation. They may also learn how best to engage with the conversational partner, through subtle signals such as timing of remarks, tone of voice, gesticulations, and so on [Hall 1983]. Each thing learned, whether it be information about a topic or the speaker, becomes a springboard for further exchanges in the conversation. Indeed, the conversation becomes a lesson about conversation itself [Bateson 1972]. Provided both partners are willing to pursue the journey, conversational turn-taking fosters mutual understanding and enhancement.

The dialogic process has implications for design, which may be characterized as a "conversation with the materials of a design situation" [Schön 1992]. In this view, designers develop understandings by engaging with and reflecting on artifacts, like marks on paper and images on screens. We believe this characterization to be insightful but insufficient. No doubt, objects and situations "talk back" to the designer [Fischer and Nakakoji 1992], but different objects and situations provide different types of feedback, more or less helpful in pursuing the "dialog." As Fischer and Nakakoji cajole, we shouldn't talk about "back-talk" unless we specify what the object is saying!

For example, an artifact that is too malleable ends up mirroring its conversational partner's own will and becomes boring after a while. On the other hand, an artifact that is too unresponsive or inconsistent may become uninteresting because its partner cannot rely on it. We believe that much can be learned from engaging with an artifact that has a "will" of its own, even if it constrains the conversation in particular ways. Interactions with artifacts should be portrayed as conversations only if the artifact has some degree of autonomy. The conversational partner must have integrity, even if idiosyncratic, or it will lose its "holding power" [c.f. Papert 1980].

Magix environments assume the autonomy of both conversational partners, the learner and the computational artifact. In designing the environments, we considered the kinds and degrees of control to afford both users and the system. We also considered the question of *who* can enhance *whom,* and when.

A person building tiles in PatternMagix or creatures in AnimMagix establishes certain conditions, but then the system takes its turn, augmenting or varying what the person initiated. Then the person reassesses and builds again. Alternations and variations in degrees of control encourage contemplation at times and creative building at others. At times control is cast as quick turn-taking between the artifact and the person; at other times, often within different modes, control varies within prolonged opportunities for construction or contemplation.

Multivariate Systems as a Domain of Interest

Variable control modalities are especially appropriate for explorations of dynamic systems. Understanding these complex, often unwieldy entities is important – they are everywhere. Indeed, the world operates as a network of interdependent, multivariate systems. Both biological and physical phenomena can be understood in these terms. Such systems include weather and traffic patterns, population growth, economic fluctuations, biological evolution, and organizational behavior [Forrester 1992, Resnick 1994].

The frequently invoked image of a butterfly affecting the course of a hurricane testifies to people's fascination with the relevant qualities of unpredictability and emergence. These qualities, though intriguing, make dynamic systems hard to understand. Nevertheless, as rapid technological development escalates environmental and economic concerns to global levels, people are increasingly motivated to grapple with these complex phenomena. In so doing they must confront their own curiosities and apprehensions about the subtleties of the systems' control mechanisms.

The world naturally provides materials and situations in which children can develop their intuitions through experimentation. In this way they learn about basic notions of space, number, social interactions, and so on [Piaget 1951]. Nevertheless, the focus and power of such experiments can be augmented through purposeful intervention. Designed artifacts and environments can make experiments possible for which there are no natural supports, or for which the natural resources that exist are insufficient.

While the world is rich in instances of dynamic systems, it does not readily provide representations and materials that help people to study them. With computer technologies we can model and simulate the dynamics of complex systems. Magix environments offer a particular means of experimenting with their behaviors. People of all ages can build systems that are microcosmic, though still complex, and contemplate the often unexpected effects that emerge as the dynamics play out. Building with partial control reflects the elusive quality of such systems: one can never totally control them, but can effect interesting changes by intervening.

Microworld Design

Microworlds are carefully crafted artificial settings for creative exploration. Like playpens and sandboxes, they contain materials and tools for specific kinds of play in particular domains. In creating microworlds, learning researchers become designers: they pay careful attention to the materials and the tools, and to the relationships between them.

Microworld designers look for essential characteristics of a phenomenon, paring away distracting features and enhancing salient ones [Papert 1980, Edwards 1994]. Of interest are core aspects of the phenomenon, without which it would cease to exist. These aspects include objects characterized by specific properties, and operations with which the objects can be transformed. In the example of Turtle Geometry, the graphical turtle has two basic properties, position and heading [Papert 1980]. By operating on them with simple translations and rotations, a learner can build increasingly complicated geometric figures – and with them, progressively deeper understandings of the geometric domain.

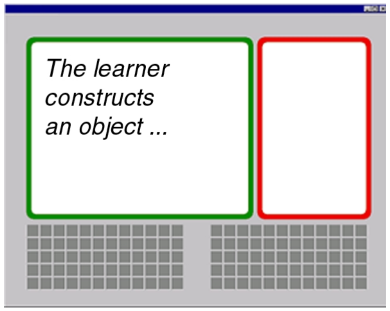
The Magix series supports playful exploration of part-whole relationships and emergent effects in the domain of dynamic systems. PatternMagix uses the age-old aesthetics and intrigue of tiling patterns to engage children in a world of geometric symmetries. AnimMagix builds on time-honored combinatorial puzzles and the universal fascination with animacy to engage children in a world of social dynamics.

In PatternMagix, children play with colorful tiles and basic geometric operations, with which they forge mosaic-like patterns. The operations of geometric symmetry include rotations and reflections, and support generation of *groupements* of transformations [Gruber and Vonèche 1977]. For example, a reflection around the y-axis (a Flip) and a reflection around the x-axis (a Drop) are equivalent to two 90-degree rotations (Turns).

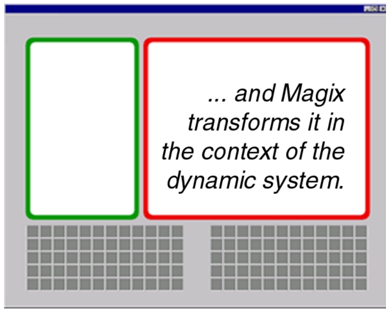
In AnimMagix, children create whimsical creatures and then launch them onto a field in which the creatures interact, affecting one another's behaviors. Learners work with fundamentals of social dynamics. They explore ways in which drives combine with sensory perception and motility to regulate interpersonal distances within dance-like patterns. Combinations of these attributes generate composite, seemingly purposive behavioral patterns. Again *groupements* characterize the dynamics: an outside observer would perceive the overall pattern of a dyadic dance as being the same even if attributes of the two creatures were reversed. For example, if creature A attracts and creature B repels, the dance would be equivalent to creature A repelling and creature B attracting.

Interaction Design for the Magix Series

While each Magix game facilitates constructions within its own particular domain, it adheres to a framework guiding interactions for the entire series.

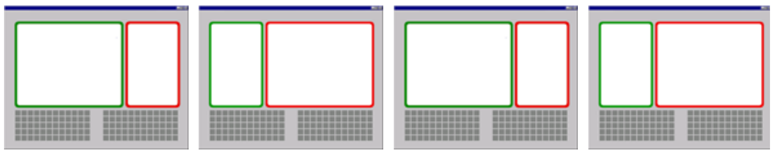


Magix games interpret and translate actions associated with a metaphorical conversation. The dialog is between the system and the person using it. Magix opens by presenting a building area at the left of the screen, which the person uses as a kind of atelier for creating objects. Here the learner has total control, freely selecting components from an existing set and using operations to modify them.

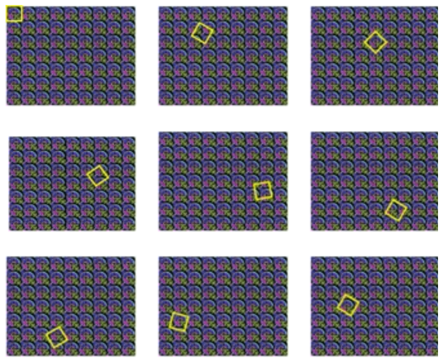


The *build* process is followed by a *launch:* When the learner places the constructed object in an activation area at the right, the area enlarges and Magix takes its turn in the dialog. The software automatically replicates, varies, and/or animates the object, transforming it within the larger context of the multivariate system to which it belongs. The object becomes part of a dynamic whole.

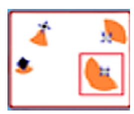
With the rightward gesture that delivers control to the Magix



system come unexpected, often delightful effects that emerge immediately: in PatternMagix, a colorful geometric pattern appears, and in AnimMagix, a dance of mutually responsive creatures begins. As the person and Magix take further turns in the "conversation," the two screen areas shrink and grow according to who is in control at a given moment.

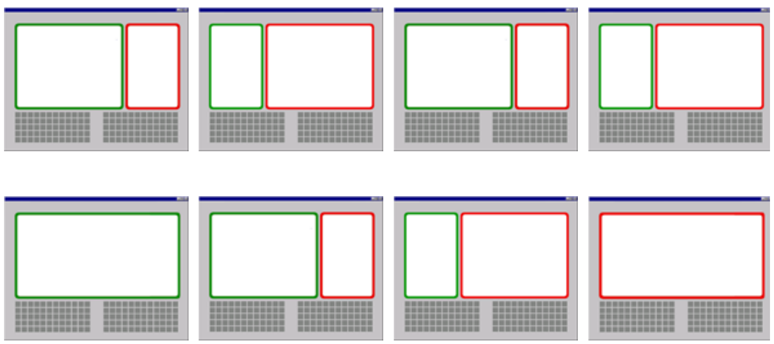


When the activation area is enlarged, Magix transforms the constructed object and may suggest further moves. The transformed object appears in the context of the overall system, and a movable Frame can call attention to different parts of the display. In this way Magix encourages both contemplation of the whole and focus on a particular part.



The learner can *convene* by revisiting the constructed object. The Frame enables selecting and saving excerpts for continued exploration. Thus learners have latitude for thinking from new perspectives and working within the systemic context as it unfolds, rather than according to a previously formed plan. *Bricoleurs* can engage comfortably.

Learners' selections are saved to a library area at the bottom of the screen, augmenting the set of objects available as components for new creations. Each time the person begins creating a new object, she can start from scratch or work from an existing component in the library. A library entry becomes a resource for the continued conversation, a "prop" that can support deeper inquiry into the nature of the system and its



constituent elements [c.f., Bellamy et al. 1994].

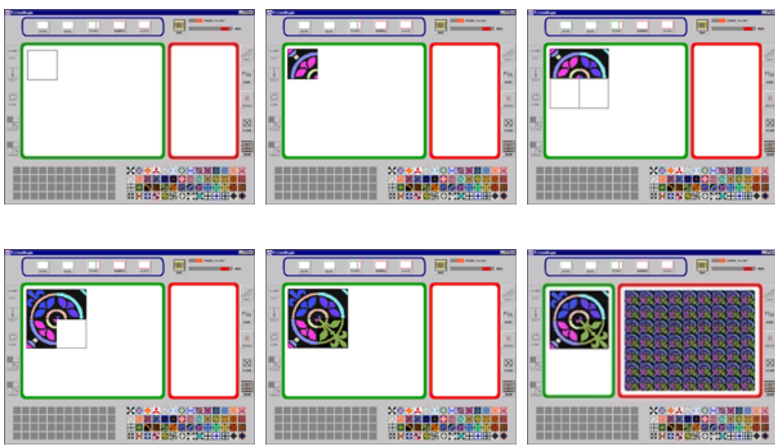
The library also holds pre-made entries and contributions from others who have used the Magix environment. Thus it becomes a third interlocutor in the metaphorical conversation. It is a resource through which certain conversational moves can be mediated. Some of these moves embellish the turn-taking between the building area and the activation area. The person creates an object at the left and moves it to the right; Magix transforms the object; the person captures an aspect of the transformation and saves it in the library; then the person moves the selection from the library to the building area for further constructions. As players become more and more attuned to playing with Magix, they become proficient with this gestural and conceptual cycle.

Additional modes increase the range of Magix functionality. The selectable modes enable varying degrees of control, broadening opportunities for both creation and contemplation. In addition to the opening mode in which the left and right screen areas change size as the person and Magix take turns, there are modes in which the person has total control when creating objects and modes in which Magix has total control when transforming them. Switching from mode to mode diversifies ways of engaging with objects and the systems in which they interrelate. Mode-switching, like the pronounced turn-taking of the opening mode, broadens but extends the constructive-dialog style of interaction.

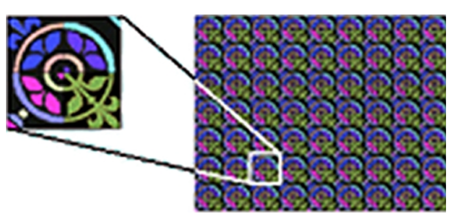
Thus Magix provides many options for creating and contemplating objects and relationships between them. Usage trials with our initial prototypes suggest that individuals may tend to favor one mode or another, demonstrating different preferences for engaging with the constructive-dialogic tool.

Interaction Scenarios

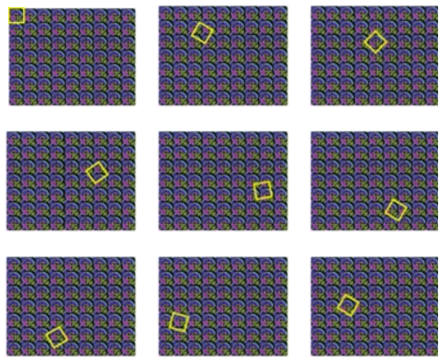
PatternMagix



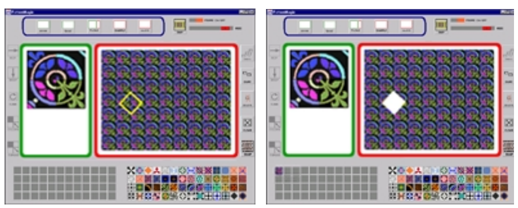
When PatternMagix opens, it greets the person with a metaphorical invitation to construct a tile. This invitation takes the form of an empty square in the building area at left. The person selects a tile from the Library to fill the square, completing one quadrant of the construction. The person can then select other tiles from the Library, or add copies of the same tile, and can transform the images by clicking buttons associated with basic operations of geometric symmetry. (Flip reflects the tile around the y-axis; Drop reflects it around the x-axis; and Turn performs a 90-degree rotation to the right.) Magix places each new tile within the quadrant-grid structure, left-to-right and top-to-bottom. This manner of construction is unique to the opening mode, called Tiling mode.



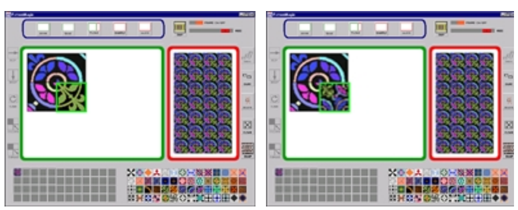
When the quadrant-grid is completed, the learner can continue the dialog by clicking the activation area at right. Magix interprets the contents of the grid as a new tile, which it shrinks and replicates to create a pattern. Emergent effects become visible immediately, in the form of patterns within the pattern.



Magix then suggests possibilities for selecting new tiles from within the larger pattern. A bright Frame appears around the original tile at the upper left. The Frame lingers momentarily and then begins to float randomly around the pattern. The Frame moves slowly, changing orientation as it goes. The person can stop the movement by clicking directly on the Frame, freezing its orientation. She can then reposition it, adjust its size, or make it disappear altogether. If she turns the Frame back on, it reappears and resumes its free-floating movement.

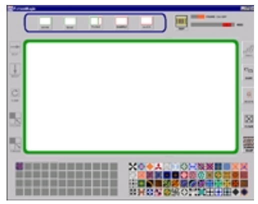


When the Frame satisfactorily delineates a portion of the pattern, the person can click the Snip button to capture it. The selected area rotates to an upright orientation, if necessary, and appears as a tile in the Library, becoming available for further constructions.



When the person clicks on the building area at left, the windows adjust size accordingly and a new constructive dialog can begin. The person can incorporate the Library's new element by clicking one of the quadrants and then clicking the tile. It appears in the highlighted quadrant. The person can continue working with this tile, add other tiles, or clear the area and begin a new construction.

Using the constructive-dialogic style of interaction and three simple geometric transformations, the learner can create and explore countless patterns. Countless others become possible as the person works in different modes, which enable varying degrees of control in the dialog with the system. Manual modes maximize the person's constructive capability, and automatic modes maximize the system's contribution.



In the two manual modes, Draw and Quilt, the building area expands to its maximum width, and the person's creations result solely from direct manipulation. Thus the "conversational" style is more monologic and the person has maximal control.

In Draw mode, the person creates freehand decorations for tiles.[3] These personalized tiles can be saved in the Library, becoming available for use in other modes. In Quilt mode, tiles dragged from the Library become "patches" in a freeform "quilt." The person can use the Frame to bound new areas across patches. These unique selections can also be saved as new tiles in the Library.

In the two automatic modes, Shuffle and Kaleid, the activation area expands to its maximum width, and the system automatically generates variations of learner-crafted patterns. The learner relinquishes control temporarily but can contemplate the evolving transformations.

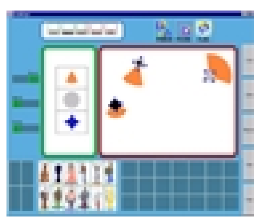
In Shuffle mode, the system repeatedly applies a series of transformations, generating a dynamic pattern. Varying

sequences of the basic operations of geometric symmetry – Flip, Drop, and Turn – create intriguing effects that can inspire new creations when the learner moves to more constructive modes. In Kaleid mode, variations of basic tile shapes support explorations of more complex patterns.[4] Squares can become triangles, hexagons, or other intermingled shapes.

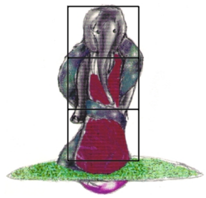
Thus each mode presents ways of generating tiles and/or patterns. The Library acts as a bridge between modes: new tiles created with the Frame and saved in the Library become available for further exploration in various modes.

AnimMagix

In AnimMagix, we move from the realm of geometric tiles and patterns to explorations of dynamics in social transactions. The constructive parts are now creatures' behaviors, and the patterns are interactions among sets of behaviors.



Learners create whimsical creatures with anthropomorphic attributes and launch them onto a field in which the creatures interact and affect one another. The creatures become like acrobats on hoverboards or dancers on an ice rink. Their intentions seem to change as they glide from one partner to the next. Learners can explore emerging social patterns by selecting and saving sets of behaviors for closer study. AnimMagix maintains the constructive-dialogic style of interaction, as well as many functions introduced in PatternMagix.



When AnimMagix opens, it presents an invitation to create creature. This invitation takes the form of a tripartite column within which the learner selects behaviors that define the creature's "personality." These selections occupy areas matching the head, the belly, and the base.

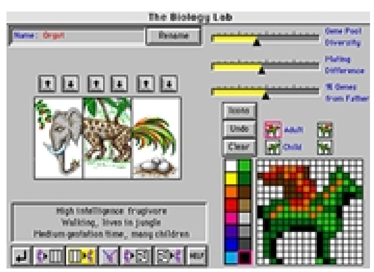
This manner of composite construction has become familiar through its use in toys, books, and software packages:

At left: "Animal Twister" by Club Earth, Cumberland, RI.
At right: Applause™, ©1995 JHP, China.

The kangaroo blurb reads: "This animal bounds happily around in Australia. It is quite harmless but it even carries its babies around in a neat little pouch when they are young."

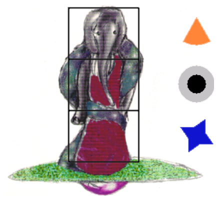
The pengaroo blurb: "This creature should be able to fly. But it can't. It can however swim very well and it even carries its babies around in a neat little pouch when they are young."

From J. Riddell, Hit or Myth: More Animal Lore and Disorder.
NY: Harper and Rowe, 1949.

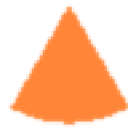


SimLife's Biology Lab uses a similar approach for making new creatures, but adds features that help distinguish it as a learning environment for ecology and genetics: users can modify the species genome, gene pool diversity, degree of difference between parental genes, and number of paternal genes.

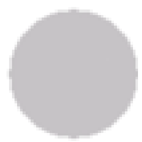
From K. Karakotsios et al., SimLife: The Genetic Playground. *Orinda: Maxis, 1992.*



AnimMagix users endow creatures with behaviors that the computer sets into dynamic relationship. The behaviors are assembled within a tripartite construction column, similar to the quadrant grid for tile construction in PatternMagix. Each part of the creature has an associated behavioral attribute, which is represented abstractly.

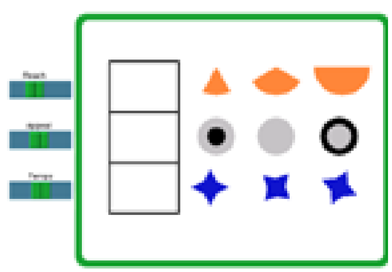


The head is associated with the creature’s perceptual field; it establishes the range within which the creature can sense and respond to aspects of its environment, including other creatures.

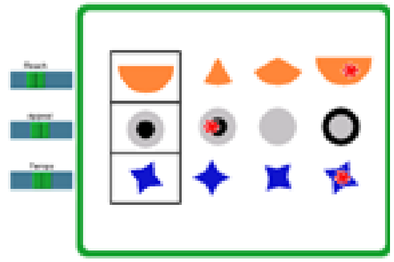


The belly is associated with the creature’s sociability, or appeal. A creature can attract or repel another creature, or remain neutral. If it attracts another creature, it lets it get close; if it repels another creature, it pushes it away.

The base is associated with the creature’s motility; it establishes the creature’s stubborn preference for a specific pattern of movement. It is a dance-in-place that pertains to a creature’s self-image with respect to physical capability and style of movement. A creature can maintain a steady heading, sway back and forth like a windshield wiper, or spin in repeating circles.



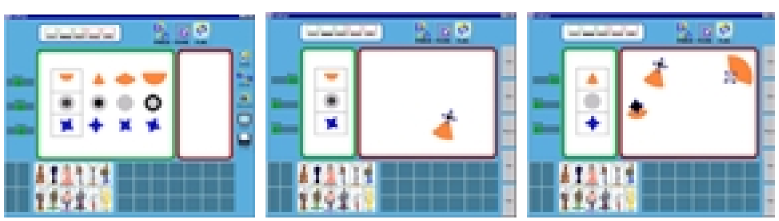
The learner can vary the breadth of a creature’s perceptual field by selecting narrow, medium, or wide angles for the periphery. She can use the associated Reach slider to vary depth of the perceptual field. Likewise, the learner can select attract, neutral,



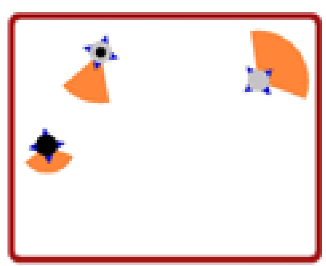
or repel characteristics for the creature's sociability, and use the Appeal slider to vary degrees of attraction or repulsion. The learner can also select still, swaying, or spinning patterns, and use the Tempo slider to adjust the speed of movement.

Here, the learner has constructed a creature who has a wide-range periphery in the perceptual field, who attracts other creatures in its field, and who spins continuously.

To create creatures with behaviors, the child works in the opening mode of AnimMagix, called "Enact" mode. Like the Tiling mode in PatternMagix, Enact is the mode in which the constructive-dialogic style of interaction is most pronounced. The building area at left and the activation area at right grow and shrink as the learner moves back and forth between them.

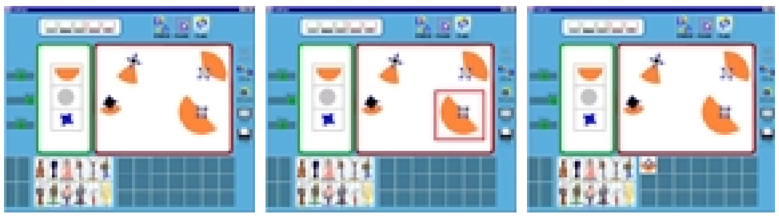


The learner constructs a creature by assembling its behaviors at the left. Then she clicks on the area at the right to activate the behaviors and view the moving creature from above. By going back and forth between the left and right areas to build and launch several creatures, the learner see how they relate dynamically over time. As the creatures interact, behavioral patterns emerge and evolve.

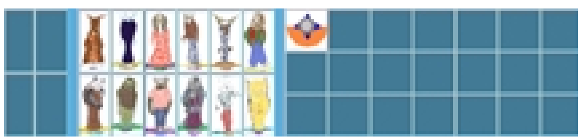


At first it is the zany movements that command attention, but gradually one realizes that subtle interrelationships between the creatures' perceptivity, sociability, and motility contribute to the overall dance. It invites contemplation as the creatures move around the screen. Often they swarm in clusters that later break apart as one creature darts off toward another.

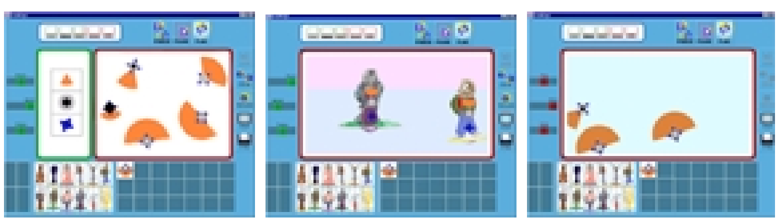
AnimMagix provides several ways to examine the creatures' interrelationships. The learner can click a creature to stop its movement (though the behaviors remain active). She can then relocate it, clone it, or use sliders to adjust its behaviors. Clicking again restarts the creature's movement. The learner can also stop and restart the action of all the creatures (Freeze / Fray), and can mark individual creatures so they are easier to follow in the fray (Flag).



As in PatternMagix, the learner can use the Frame to resume the conversation with Magix.[5] Individual creatures can be selected and saved in the Library, where the set of behaviors becomes available for further exploration in other modes.

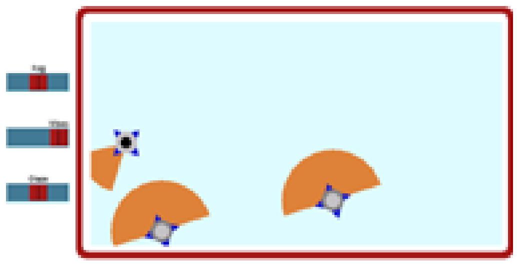


The Library includes three sections: one holds creature behaviors, another holds ready-made creature appearances, and another is for appearances that learners design themselves.



Creature behaviors can be moved from the Library back into the Enact mode's activation area, or into the Mingle or Stage modes. In Mingle mode, the learner can bring behaviors and animalistic appearances together. The figures behave as in the bird's-eye views, but the view is frontal and the effect is like a puppet show. As in the Quilt mode of PatternMagix, learners can freely position the objects. In the Mingle mode of AnimMagix, learners can also freely outfit them as particular creatures.

The sliders in Stage mode simultaneously affect the behaviors of all the creatures, which has the effect of changing the "environmental conditions" of the activation area. Thus the three sliders become analogs to the Reach, Appeal, and Tempo sliders in Enact mode.



The Fog slider changes the Reach, or depth of all the creatures' perceptual fields, which creates the illusion of increasing or decreasing fog in the environment. The activation area darkens or lightens accordingly. The Vibes slider changes the Appeal, or degrees of all the creatures' sociability, as though mood-effecting "charges" were sent through the air. The Glaze slider changes the Tempo, or all the creatures' swaying and spinning, which has the effect of adjusting friction in the environment.

In Enact mode, the sliders affect individual creatures, and this correspondence guides thinking about how the sliders work. In Stage mode, however, even though the sliders affect each of the individuals, one tends to think about their effects in terms of the environment. This inversion constitutes *groupement* of sorts in this metaphorically biological realm. Individuals are inextricably bound to their environments.

In Stir mode,[6] changes again simultaneously affect all of the creatures, which again are seen from above. However, as in the Shuffle mode of PatternMagix, the changes happen automatically. The system adjusts environmental conditions according to patterns that are fixed but not readily apparent to the user. These adjustments occur as alternating sequences of Fog, Vibes, and Glaze effects.

The Draw mode would be an important mode of play in AnimMagix. The learner would use it to design costumes for creatures' behaviors. These appearances could be saved in the Library for use in other modes.

Further Work

The prototypes described here are sketches that preliminary users enjoy, but which nevertheless could benefit from further design iterations to refine each application and to make the overall series even more engaging. We are concerned primarily with two directions for further development: portability, and an expanded range of input and output capabilities. Both of these directions would help to make the Magix device more personally appropriable by users of varying ages.

Children use workspaces differently from adults. They need to change position often – squirming, sitting, standing, and jumping complement and express children's thinking. It's important to support these changes rather than inhibit them. Furthermore, children like to have their own objects to play with. These objects need to be lightweight, colorful, durable, and, above all, portable. A carefully designed platform for the Magix series should fit these requirements. With it, children could play quietly at home, amuse themselves while riding in a car seat, show the toy to friends on an outdoor playground, and so on.

Realizations of the Magix series can rely on devices associated with standard laptop computers, such as trackballs or thumbpads. Ideally, though, the series would be supported by a self-contained device that children could carry and which would present the functionality playfully and colorfully. The carrying case should have different input devices (such as stylus, plug-in books, kaleidoscopes, tripartite creature-construction toys, and the like). Such devices would demonstrate and support rich experimentations with relevant phenomena.

Conclusion

In Magix games, the manner of work and play is as important as the topics available for exploration. Through varying control modalities, children construct objects and patterns, and then experiment with changes to see how one variable can infuence the behavior of an entire system.

By constructing and transforming their own creations in particular microworlds, learners can develop progressively deeper understandings of geometric symmetry and social dynamics. Equally important, learners can develop intuitions about the more general Magix theme of part-whole relationships within dynamic systems. Beyond these inquiries, learners can develop a model of scientific practice that emphasizes ecology rather than domination [Bateson 1972, Fox Keller 1985]. This perspective develops through sharing control and observing the balance of influences among many players within a given system.

In *bricoleur* fashion, Magix users act as both designers and scientists. They "mess around" with properties of dynamic systems, developing robust intuitions about the complex phenomena that characterize them. By encouraging several kinds of conceptual development, Magix environments engender foundations for more formal study of topics in math and science.

Notes

[1] Seymour Papert introduced the term "microworlds" in his book, *Mindstorms* [Papert 1980]. For a discussion of microworld-style learning environments, see page 12 of this paper.
[2] For illustrations, see Appendix 1, "PatternMagix Functional Description."
[3] The prototype does not include an implemented Draw mode, which would include tools and operations familiar through many existing draw programs.
[4] This mode is also reserved for future development.
[5] For further explication of similarities to PatternMagix, see Appendix 2, "AnimMagix Functional Description."
[6] Like the Draw and Kaleid modes of PatternMagix, the Draw and Stir modes of AnimMagix exist in our design but are reserved for future development.

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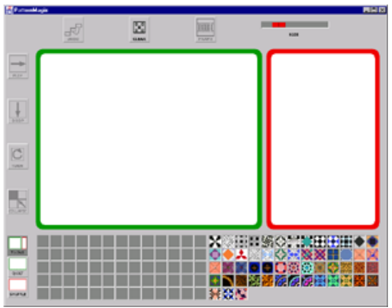
Appendix 1: *PatternMagix* Functional Description

The learning environment presents four distinct conceptual and physical areas.

Child's Area for creating playthings

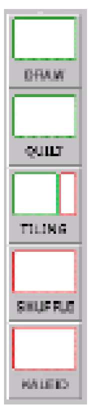


System's Area for automatic transformations

Buttons for modes of work, general functions, and specific operations

Library with ready-made entries and empty slots for child's creations

There are five modes:
Draw, Quilt, Tiling, Shuffle, and Kaleid.



DRAW: The child designs a tile by hand.

QUILT: The child arranges tiles into patterns by hand.

TILING: The child and system alternate as the child builds tiles and the system spreads them into patterns and suggests selections for new tiles.

SHUFFLE: The system introduces variations in a pattern by repeatedly applying operations of geometric symmetry.

KALEID: The system introduces variations in a pattern by applying kaleidoscopic transformations.

These modes range from maximal degree of control for the child to maximal degree of control for the system.

General functions include
Undo, Delete, Clear, and Frame.

UNDO: The system returns to the previous state.

DELETE: An individual unit is removed.

CLEAR: Everything from the active area (child's or System's) is removed.

FRAME: A yellow box that delineates an area to be defined as a new tile.

ON / OFF: Toggles the Frame off and on.
SIZE: Adjusts the size of the Frame.

Specific operations include
Flip, Drop, Turn, and Collapse.

FLIP: Transforms a tile around the Y-axis.

DROP: Transforms a tile around the X-axis.

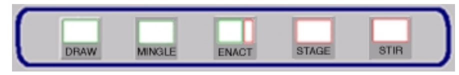
TURN: Rotates the tile in 90-degree increments.

COLLAPSE: Tiles build as quadrants stacking left-to-right and top-to-bottom. Collapse shrinks them to a single quadrant, then defined as a new tile.

Appendix 2: *AnimMagix* Functional Description

The general functions are the same as in PatternMagix:

Undo reverts to the state immediately preceding an action.
Clone duplicates a selection.
Remove deletes a selection.
Clear empties the active window.
Snap prints the contents of the active window, capturing the action at the moment the button is clicked.



AnimMagix has five modes in which the child can play with creatures and their behaviors: **Draw**, **Mingle**, **Enact**, **Stage**, and **Stir**. The child initiates moves to verying degrees in the different modes. Modes also vary in their focuses on creature design and the child's ability to examine creatures' behaviors and see how they effect one another.