Physical Spaces and Mathematical Explorations: *A Pattern Language*

Workshop presented at the OAME Conference:
Learning Systems: The Case of Mathematics for Teaching

Dr. Rena Upitis
Queen's University
Kingston, Ontario, Canada

This work is supported in part by the Social Sciences and Humanities Research Council of Canada, and by a nested community of colleagues, students, friends, and family: Katharine Smithrim, Ann Patteson, Brent Davis, Gary Rasberry, David Murphy Haglund, Gary Kembel, Zinta Upitis, Hayden Rasberry…

Structure of the Workshop

- Conditions for complexity (3 minutes)*
- Best work (15 minute activity with handout)
- Students' words (5 minute presentation)
- Principles of *A Pattern Language* (20 minute presentation with handout)
- Design a "Math House" (approx. 2 hour activity)*
  - Paper sketches (20 minutes)
  - Start model (30 minutes)

BREAK

  - Continue model building (60 minutes)
  - Gallery tour, patterns, complexity (15 minutes)

*BD: The missing part of the opening keynote

*ES: A system must act to learn

Conditions for Complexity*

- Redundancy
- Diversity
- Specialization
- Neighbor Interactions
- Distributed Control
- Enabling Constraints

* GK: systems thinkers



Redundancy and Diversity

- Complex collectives have abundant redundancy and diversity*.
- Diversity is the source of a system's flexible response—its intelligence.

* GK

Specialization



- In all complex systems, specialization must occur.
- Increased specialization reduces robustness, but increases creative possibility.

Neighbor Interactions



- The agents of the system need to “bump up” against one another.

- In a knowledge-producing system, the “agents” aren’t people, but ideas.

Decentralized Control



In a complex system, control is dispersed; there is no "queen ant".*

* GK: "distributed leadership"

Enabling Constraints



- Complex systems contain structures.
- *Enabling constraints* impose sufficient limits to orient learners and sufficient freedom to allow for the emergence of the unexpected.*

* GK: enablers

Educational reform cannot happen in most contemporary schools. Architects and educators must come together to determine how the natural and built environments can change in concert with emerging theories about teaching and learning.

Architecture and Complexity

What if *both* architecture and the curriculum were seen as “agents” in the nested complex systems of classrooms, subject disciplines, and school communities?

Best Work*

- home, natural light, hot beverage
- home VS. office
- space to lay things out
- noise VS. quiet
- temperature, natural light
- colour of room

*ES: tacit, enacted knowledge

Responses from Friday morning's group

Best Work*

- light
- space to spread things out VS. things in place
- home or home-like
- comfort
- natural lighting, window
- table and chair
- natural light
- place to put things, not to be cramped
- carpet VS. hardwood
- lighting, places in the home
- sounds (noise, music)

*ES: tacit, enacted knowledge

Responses from Friday afternoon's group

Best Work*

- meow, kitchen area, areas to spread out
- background noise VS quiet
- natural light (floor to ceiling windows)
- smells
- temperature
- working outside and coming in to write
- natural light very important
- “nesting” (drinks, snacks)

*ES: tacit, enacted knowledge

Responses from Saturday morning’s group

What Do Students Say?

Robert Coles

Harvard Educational Review, 1969

"The whole place, it's pretty bad. I'll tell you why, I will. My sister said it was like a jail the other day… I step and fall, because the floors are no good … and it's like in a war, in a battle".

I’ll tell you one thing, I’d tear this building down. There’s nothing to do but that. Then, if I could build a new school, I’d make it pleasant-like. I’d get rid of all the desks, every one of them… We could open and close the windows and they wouldn’t be stuck like now…And they could have some places, some big sofas maybe, where if you didn’t feel too good, you could lie down, or you could just sit in them sometimes, and you’d be more comfortable.

I’d like comfortable chairs, like ones that had cushions so your back doesn’t hurt and your bottom either… I’d like a sink, where you could get some water to drink, and you wouldn’t have to ask the teacher to go down the hall, and half the time she says no…We could have our books in a bookcase, and we wouldn’t have to sit in the same place all the time. And most of all, really most of all, a window in the roof so you could just look up and see the sky and the clouds and the sun and when the rain falls you could see it falling and you’d like it better, being in school.

I’d make the school warm and small and not big and too hot one minute and you’re shivering the next. I’d have a lot of little schools. I’d have every home-room a school, separate from the rest…And it’s too dark in school; way too dark. And once you’re inside, you never see the outside until the big bell rings and you can leave…[The teacher’s] chair squeaks a lot…they should get rid of that chair. And the lunchroom, it’s too big and everyone gets lost in it…we could have little sun-rooms, with plants in them, and we could go and eat there, a few of us in each one, and it would be cozy.

I think the best thing to do is tear down the old school and let it be a place for us to play, the land. Then we could build another one…outside it would have statues of our people, black leaders, like I saw in the news they had someplace, in front of some building. And you could walk right in the building without steps, and it would be good inside. They'd have a garden, with rocks and water and flowers … and they'd have a map of the world on the walls, all around everywhere, and you could stand and see all the continents and the oceans.

A Pattern Language

Christopher Alexander & colleagues

1977, Oxford University Press

- Towns and buildings will not be “alive” unless they are “made” by all the people in the society who share a common pattern language for building
- Each of 253 patterns describes a problem and a solution to that problem
- Each pattern is part of a nested network of patterns

- Patterns begin with the largest (regions and towns) working through neighborhoods, clusters of buildings, buildings, rooms, and ending with construction.
- Example of pattern network:
  - accessible green (60) connected to subculture boundary (13), work community (41), and identifiable neighborhood (14)
  - also connected to positive outdoor space (107), tree places (171) and garden wall (173)

- Premises and implications of the approach:
  - no pattern is an isolated entity
  - you must repair the world as you make something new and in so doing, the larger world becomes more coherent and whole
  - “the thing which you make takes its place in the web of nature”
  - patterns themselves are alive and evolving
  - infinite variety of designs within the formal pattern language system

- Best results when patterns are “compressed”, containing as many patterns as possible in the smallest space
  - building less expensive
  - meanings more “dense” and profound

The idea of designing our own houses, shops, schools, streets, and communities is as radical now as it was in 1977: it implies a transformation of the architectural profession

Most of the wonderful places of the world were not made by architects but by the people.

71 – STILL WATER



100 – PEDESTRIAN STREET

People who do not “rub shoulders in public” miss out on one of the most essential forms of social glue, created through simple social intercourse.

100 – PEDESTRIAN STREET



100 – PEDESTRIAN STREET

1. No cars.
2. Buildings must have very few *indoor* staircases, corridors or lobbies so that most circulation occurs outdoors.
3. Many entrances to buildings with open stairs directly from upper floors to the street.
4. Width of the street should not exceed the height of the surrounding buildings.

100 – PEDESTRIAN STREET

Related patterns:

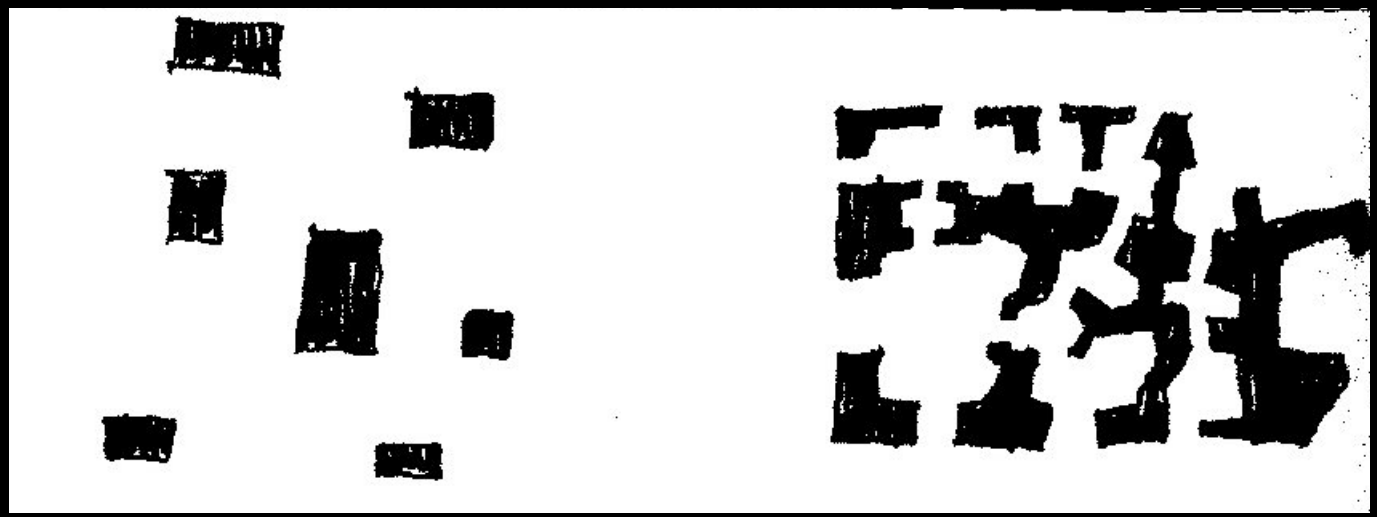
- Pedestrian density (123), family of entrances (102), open stairs (158), private terrace on the street (140), street windows (164), opening to the street (165), gallery surround (166), six-foot balcony (167), arcade (119), path shape (121) …

98 – CIRCULATION REALMS

In many modern building complexes the problem of disorientation is acute. People have no idea where they are, and they experience considerable mental stress as a result.

Make a nested system of realms in the complex, the first and largest being the complex itself.

106 – POSITIVE OUTDOOR SPACE



Buildings that create negative leftover space (left) vs. positive outdoor space (right)

107 – WINGS OF LIGHT

Buildings which displace natural light as the major source of illumination are not fit places to spend the day.

107 – WINGS OF LIGHT

1. Arrange the building so it breaks down into wings which correspond to the most important natural social groups within the building.
2. Make each wing long and as narrow as possible (never more than 25 feet wide).
3. Use wings to form outdoor areas – e.g., courtyards which live (115)

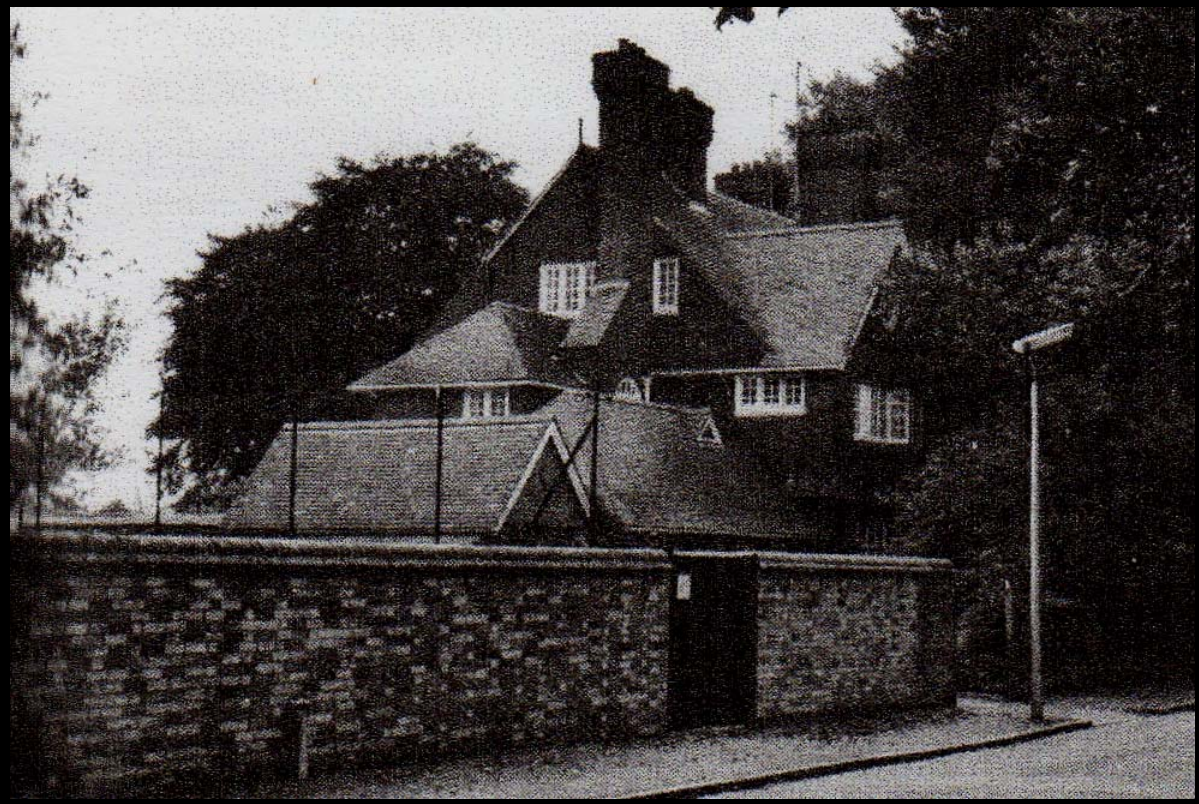
115 – COURTYARDS WHICH LIVE

Courtyards in modern buildings are very often dead. They are intended to be private open spaces for people to use, but they end up unused, full of gravel and abstract sculptures.

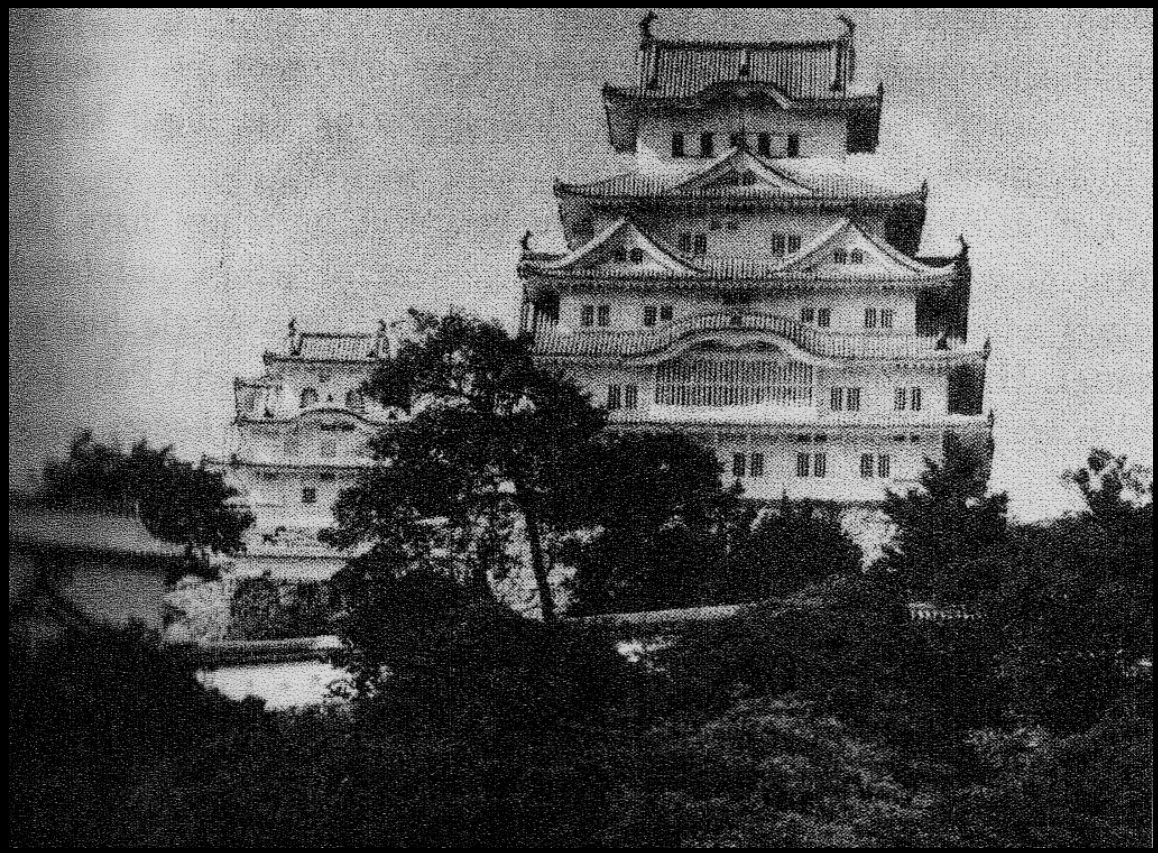
115 – COURTYARDS WHICH LIVE

1. Create ambiguity between indoors and outdoors (e.g., porch or verandah that people naturally pass onto often and can pause and go the other way)
2. Multiple entrances to courtyard on at least two opposite sides (if there is only one door, the courtyard never lies between two indoor activities)
3. Should not be fully enclosed
4. Should contain a view to a larger open space

116 – CASCADE OF ROOFS



116 – CASCADE OF ROOFS



117 – SHELTERING ROOF

If the roof is hidden, if its presence cannot be felt around the building, then people will lack a fundamental sense of shelter.

117 – SHELTERING ROOF

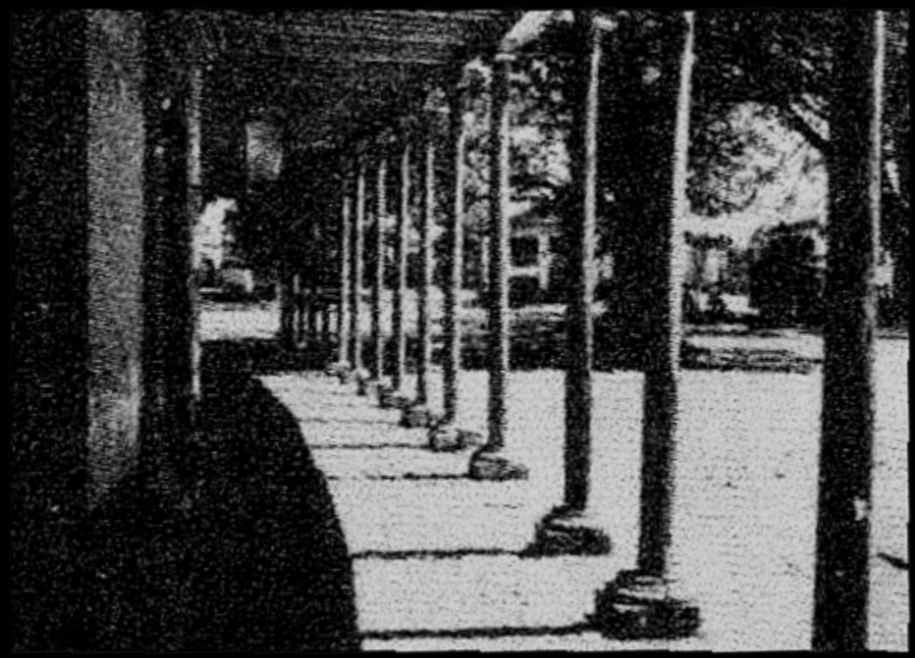


One roof lived in (left) , one stuck on (right)

117 – SHELTERING ROOF

1. Space under or on the roof must be useful space that people come into contact with daily.
2. From afar, the roof must appear to form a massive part of the building.
3. A sheltering roof must be placed so that one can touch it.

119 – ARCADES



Arcades (covered walkways at the edge of buildings) play a vital role in the way that people interact with the buildings and each other.

121 – PATH SHAPE

Streets (hallways) should be for staying in, and not just for moving through.

121 – PATH SHAPE

1. Make the shape subtly convex.
2. Include seats and galleries around the edges.
3. Roof the streets (hallways) with beams or trellis-work.

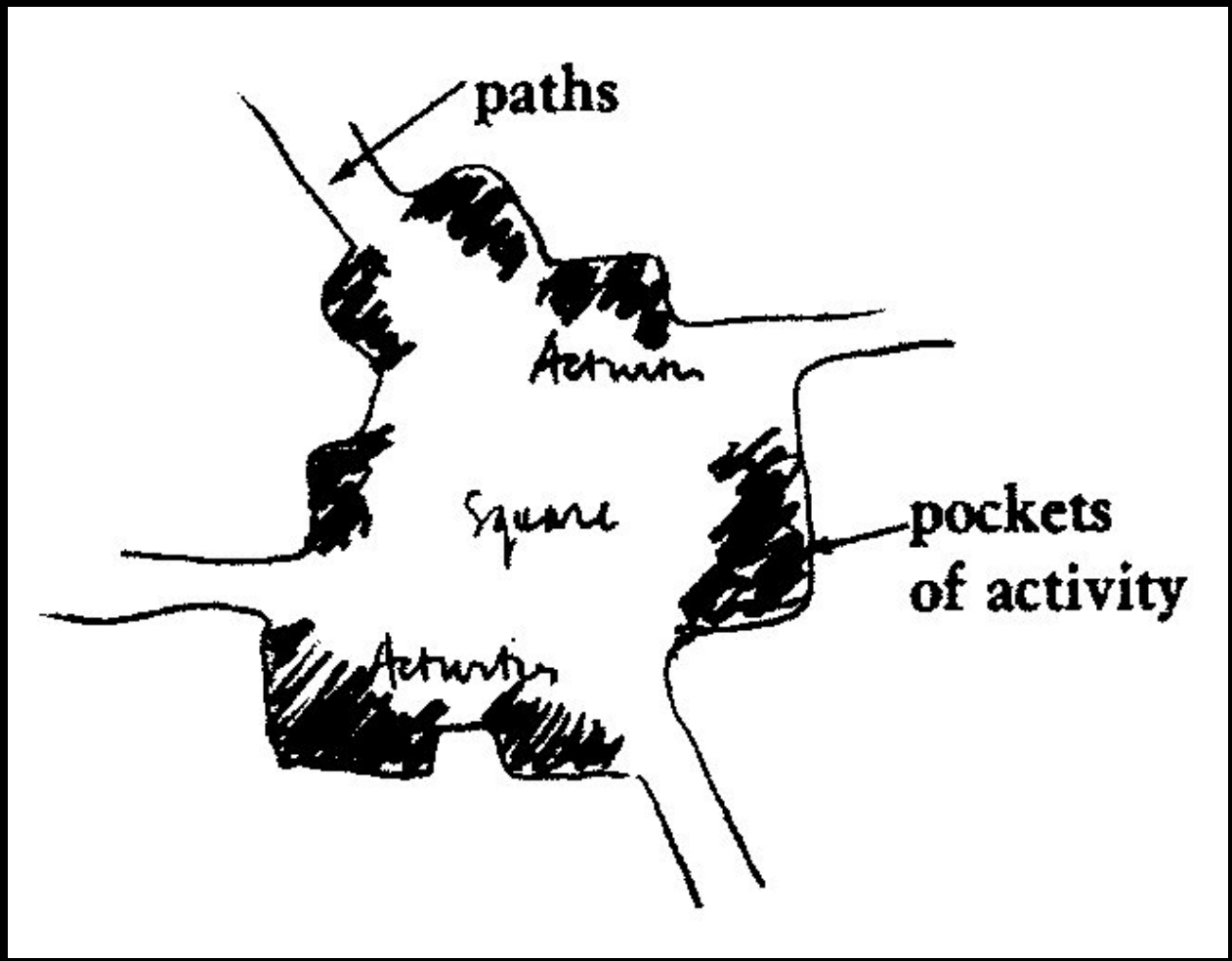
124 – ACTIVITY POCKETS

The life of a public square (area, room) forms naturally around its edge. If the edge fails, then the space never becomes lively.

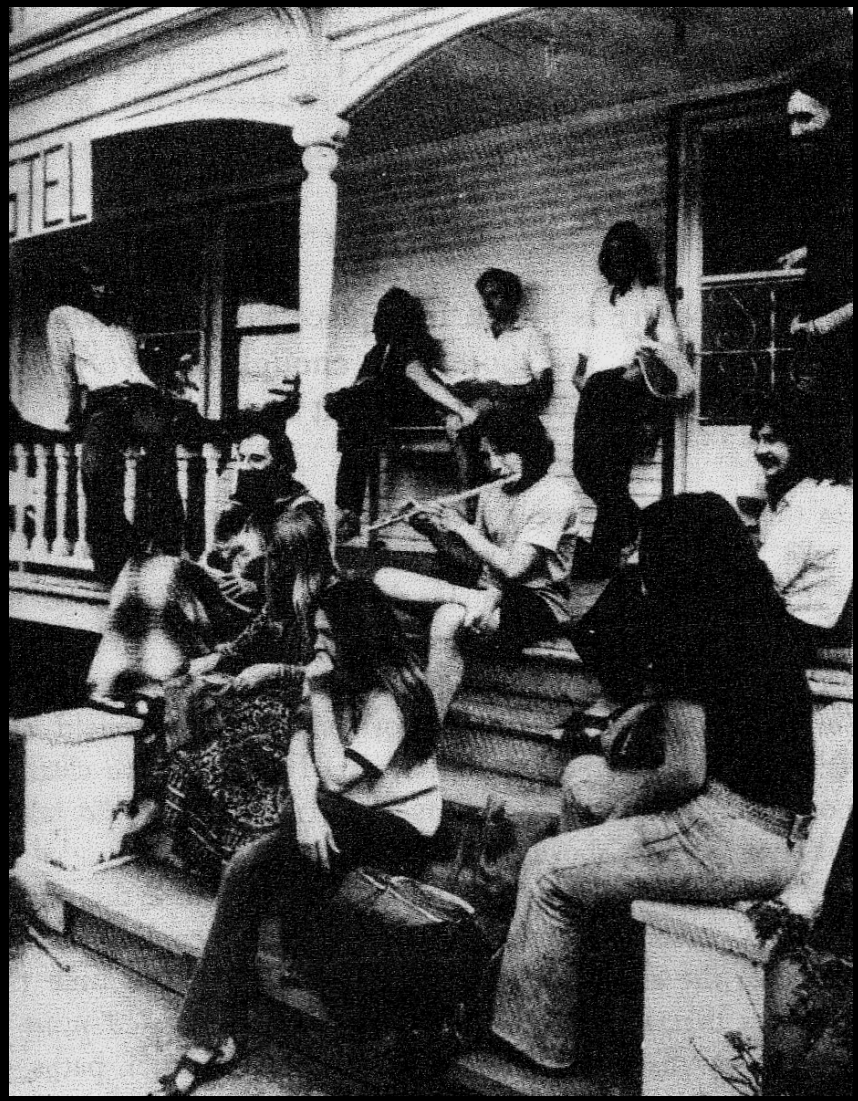
124 – ACTIVITY POCKETS

1. Surround public gathering places with pockets of activity.
2. Pockets of activity should be small, partly enclosed areas at the edges which jut forward into the open space between the paths and contain activities which make it natural for people to pause and get involved.

124 – ACTIVITY POCKETS



125 – STAIR SEATS



128 – INDOOR SUNLIGHT



129 – COMMON AREAS AT THE HEART

No social group—whether a family, a work group, or a school group—can survive without constant informal contact among its members.

129 – COMMON AREAS AT THE HEART

1. Common area must be at the “center of gravity” of the building complex, building, or building wing.
2. Must be “on the way” from the entrance to private rooms, so people always go by it on the way in and out of the building. Paths must therefore lie tangent to it.
3. It must contain the right components (kitchen and eating space, sitting space, outdoor area)

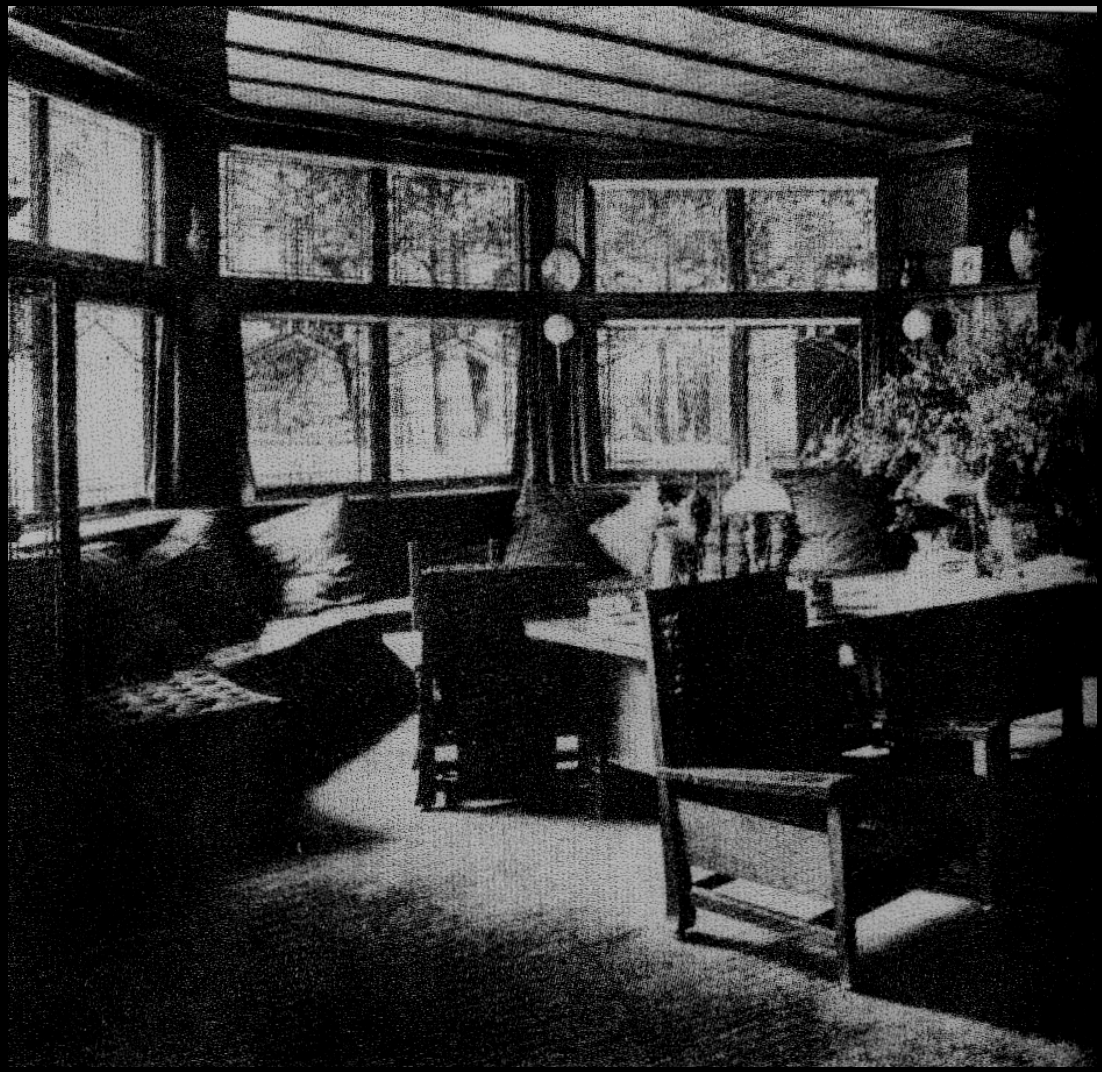
147 – COMMUNAL EATING



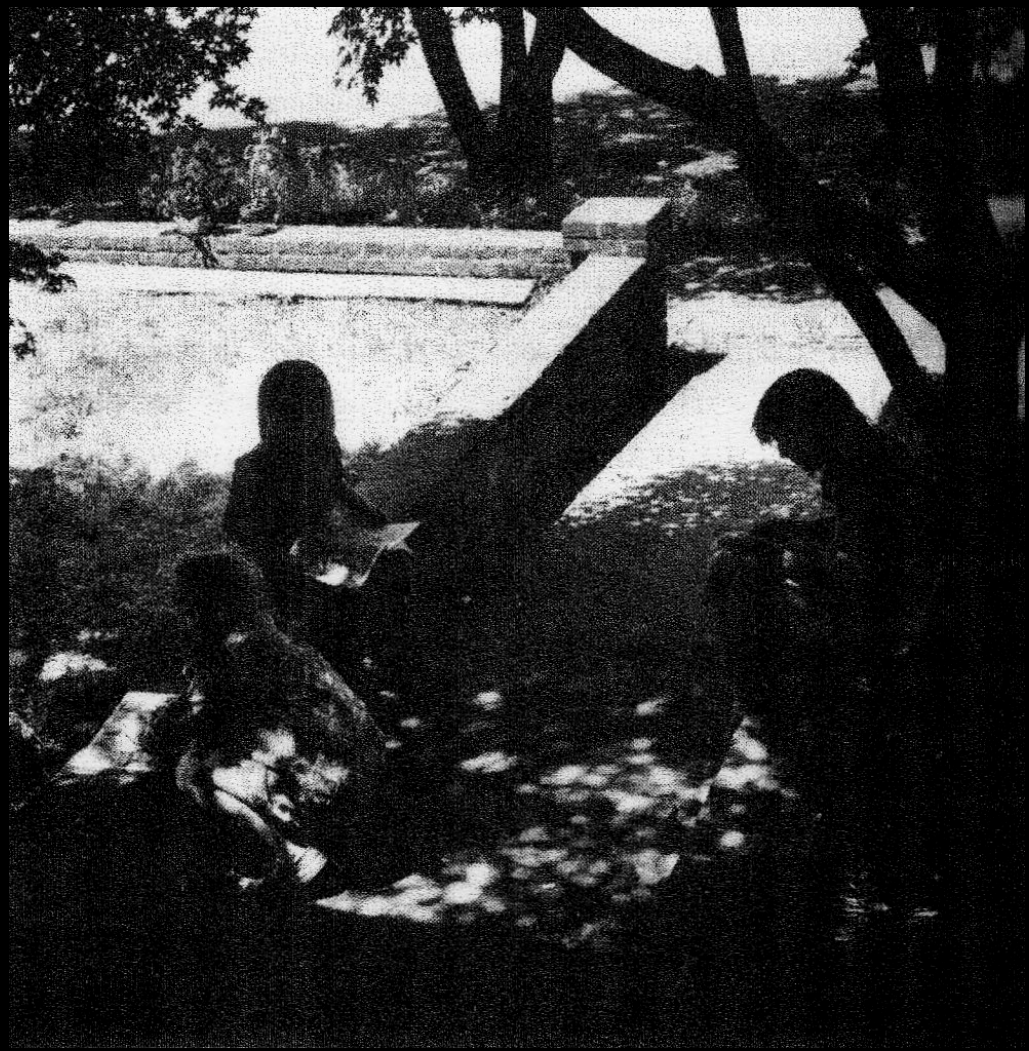
197 – THICK WALLS



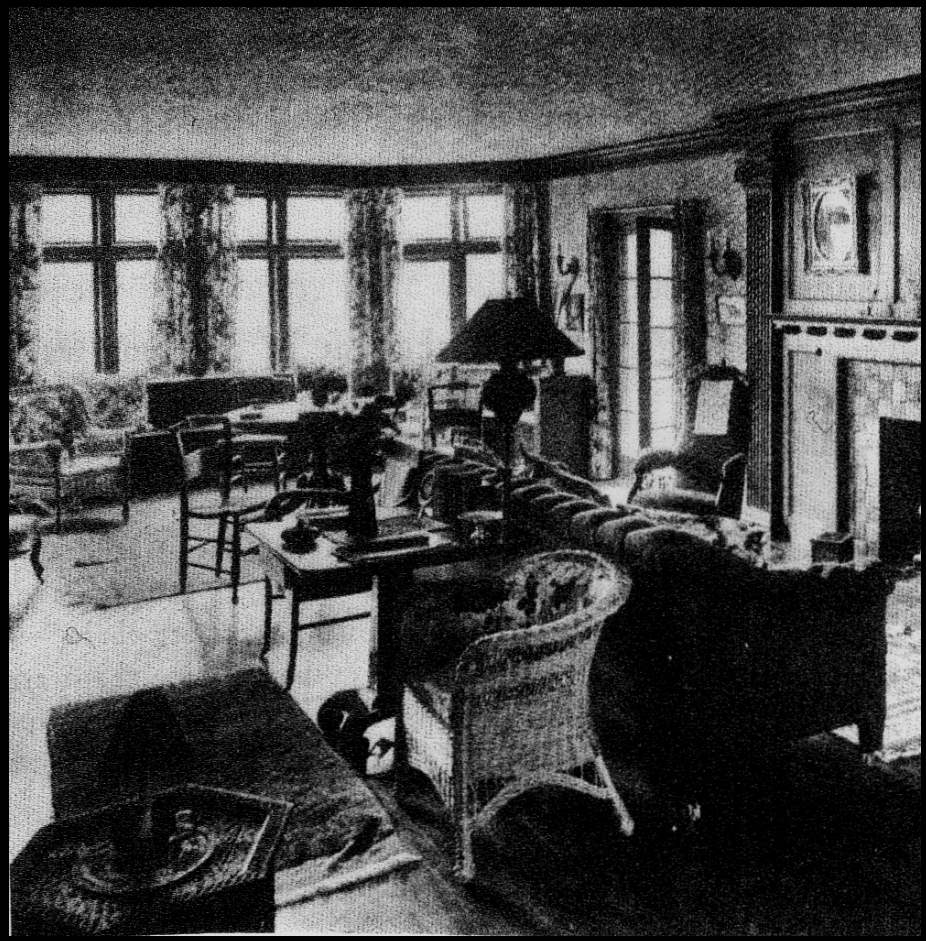
202 – BUILT-IN SEATS



243 – SITTING WALL



251 – DIFFERENT CHAIRS



Patterns and School Achievement

- Kenneth Tanner examined 44 elementary schools (23,000 students) in the State of Georgia
- School design scale based on Alexander's patterns
- After taking into account socio-economic factors, Tanner concluded two of the best predictors of achievement in language and mathematics were *pathways* (schools which had clearly defined areas for freedom of movement) and *positive outdoor spaces.*

Patterns and School Achievement

- Kathleen Yarbrough applied a modified version of Tanner's design scale
- In the third grade, the most important patterns predicting academic behaviour were *circulation* and *outdoor learning environments*
- In the fifth grade, Yarbrough found the presence of *large group meeting areas* to be the most important—meeting areas making it possible for neighbour interactions to occur readily.

Patterns and School Achievement

- Scott Andersen applied a version of Tanner's scale to 50 middle schools.
- Strongest predictors for academic achievement included *multifunctional areas, play areas, activity pockets, green areas,* and *exit doors to the outdoors.*
- In all three studies, architectural patterns dealing with the natural world and which would support the emergence of complexity were identified as most significant.

Designing a Math House

- Sketch the design with these “enabling constraints”
  - Use at least six patterns from *A Pattern Language*
  - Be prepared to explain how each pattern supports a complex system in one or more ways
  - Create a math house to accommodate 60 students and their teachers, which can be stand alone or part of a larger building
  - Draw a floor plan (and elevations, if desired) to a scale of 1/4” = 1’ with sufficient detail to build a three-dimensional model
  - Model must fit on the foam core provided
- Build the model (short demonstration)


FLOOR PLAN
SCALE: 1/4" = 1'-0"
GROSS AREA: 1508 SQ. FT.
PLANTING BED

Designing a Math House

- Gallery tour
  - View at least two other models, noting how patterns have been used to generate conditions for complex interactions to occur
  - Rejoice in the artifacts you have created!