

A developmental analysis of everyday topology in unschooled straw weavers

Geoffrey B. Saxe* and Maryl Gearhart

Graduate School of Education, UCLA, Los Angeles, CA 90024–1521, USA

Two studies are summarized on the development of topological concepts in unschooled child straw weavers from rural communities in northeastern Brazil. Study 1 is an analysis of videotaped observations of everyday teaching interactions in which expert weavers taught a targeted weaving pattern to novices. Study 2 is an analysis of weavers' topological understandings, contrasting weavers of different age levels (5 to 15 years) and weavers with age-matched non-weavers. Results of Study 1 showed that experts presented more topological information more often in demonstrations of weaving actions than in verbalizations concerned with weaving actions or verbalizations of weaving patterns; in their communications, experts tended to accommodate to learners' difficulties. In Study 2, weavers showed greater skill with increasing age and were more able to construct homeomorphic patterns for novel weaves than age-matched non-weavers. Despite their expertise, weavers performed poorly on tasks that required them to verbalize how to weave known patterns. The results suggest that weavers' generally represented topological knowledge in sensorimotor action schemes (e.g. folding under, pushing through, separating) that could be generally adapted to weaving new patterns or known patterns with new materials. The results point to the importance of investigating the various possible semiotic forms that mediate teacher–learner interactions and children's representations in everyday problem solving.

In many rural communities in Brazil's northeast, children learn to weave with straw as early as age 4 or 5, and weavers of all ages sell their straw braids to supplement family income. In their practice, straw weavers address problems of geometrical relations involving the path of a two-dimensional strand through a three-dimensional space. The geometry is a topological one in which continuities of a strand in a weave and homeomorphic relations between weaves are critical concepts. The particular focus of our analyses is (1) the way children come to acquire the skills of their craft and (2) the character of the topological knowledge children create as they become practising weavers.

In prior research with a community of Zinacanteco backstrap weavers in the highlands of Chiapas, Mexico, Greenfield & Childs (1977) and Childs & Greenfield (1980) report a pattern of apprenticeship in which, with age, child novices are gradually afforded greater participation in the practice. Greenfield & Childs also document that the Zinacanteco weavers' performance on problem-solving tasks

* Requests for reprints.

show some cognitive consequences of weaving: Children who become weavers as contrasted with children who do not are more able to represent and replicate complex patterns using coloured sticks. Our work was an effort to extend the Greenfield & Childs' analysis of backstrap weaving to the straw-weaving practice in the Brazilian communities. Like Greenfield & Childs, we were concerned with weaving as a context to study the interplay between socio-cultural and cognitive developmental processes. However, our focus was on the geometry of weaving—both the way in which geometrical knowledge is represented in everyday teaching interactions and the character of child weavers' geometrical knowledge constructed through practice participation.

Straw weaving in rural NE Brazil

During the past 50 years, distinctive weaving patterns have evolved in the rural weaving communities we studied. Figure 1 contains photographs of the principal weaves. As a part of everyday life, these patterns are acquired by children.

The varied weaving forms depicted in Fig. 1 emerged sequentially, and these forms served different functions in the social history of the practice. *Trancas* were the first to emerge—patterns which, through interviews with community elders conducted by Analucia Schliemann, we traced back 50 years; *trancas* were used to produce hats and bags to be worn in the fields and market places. *Dandocas*, weaves with straight sides, and then *bicos*, patterns with pointed sides, were later emerging weaves, first used to ornament hats and bags and now used in straw carpets. In former times, woven hats and bags produced with *trancas* were used by family members or were sold, but currently weaving's primary function is only to generate income. In current times, each weave pattern is made into long ribbons of standard length; the weaves are then sold to other craftspeople who turn the braided ribbons into bags and carpets for retail sale.

Study 1: Analyses of teaching interactions

Children learn to weave from more experienced weavers—relatives, friends, and neighbours. To gain insight into the process of acquiring knowledge of weaving and the means by which experts represent weaving to novices, we conducted a videotape study of 33 children learning from an expert how to weave a pattern that was unfamiliar to the learners but well-known to the experts—the five-stranded *dandoca*. We sampled two populations of children, one with no weaving experience and a second with weaving experience excluding the targeted *dandoca-5* pattern. We asked each of the children who participated to choose a person to teach them the new weave and then videotaped the interactions for subsequent analysis. These designated 'experts' ranged in age from 12 to adult; all adults were women, but child and teenage experts included boys.

Our analysis of teaching interactions was guided by the view that children's learning is linked to their goal-directed activities (see Saxe, Guberman, & Gearhart, 1987; Saxe, 1990). In learning to weave, these goals emerge as children negotiate their attempts to accomplish the activity with the assistance of a teacher.

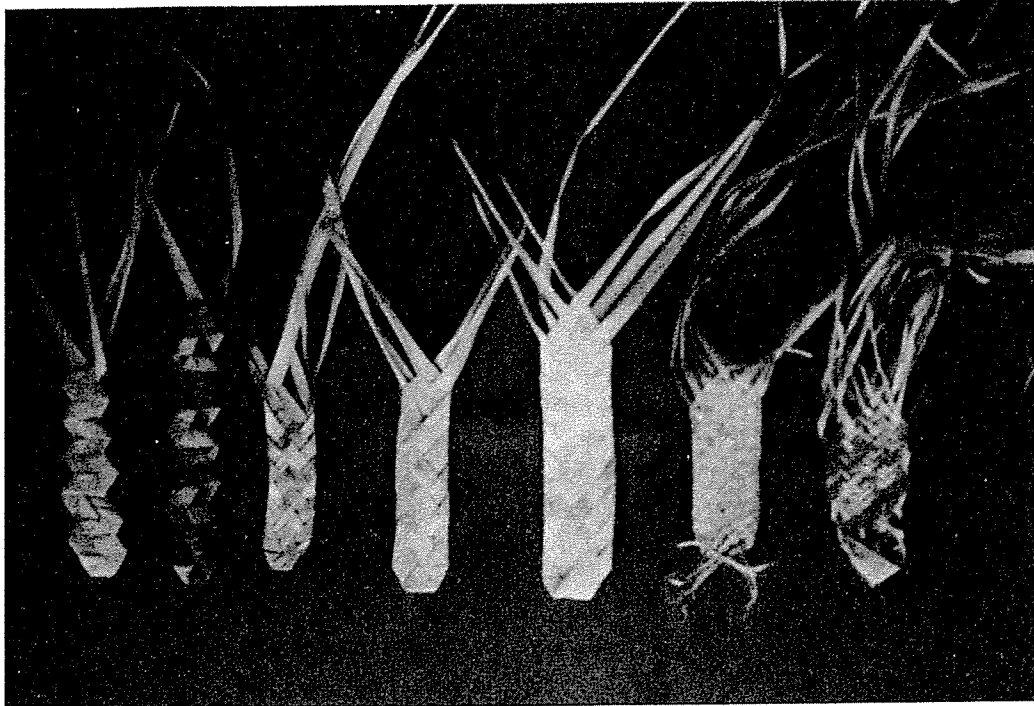


Figure 1. A selection of conventional patterns used in the targeted weaving communities. From left to right: *bico*, *bico*, *dandoca*, *dandoca*, *dandoca*, *tranca*, *tranca*.

Weaving the targeted *dandoca* can be understood as consisting of the five components indicated in Table 1. In weaving, the child must coordinate strands of straw, three on one side of the *dandoca* and two on the other. The first two components concern the sequence of actions: the weaver must identify the side on which the active strand will be chosen (it is the side with three strands), and then the weaver must choose the appropriate active strand (it is the outermost one). The next three components involve identifying appropriate topological relations: the weaver must fold the active strand under its adjacent strand, then the weaver must separate the space between the adjacent strand and its centremost neighbour; finally, the weaver must push the active strand through the space between the adjacent strand and its centremost neighbour.

Table 1 Components to weave the five-stranded *dandoca*

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1. Identify appropriate side
 2. Identify appropriate strand
 3. Fold under adjacent strand
 4. Separate the space between adjacent strand and neighbour
 5. Push strand through space
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Someone teaching a child to weave could represent weaving procedures and topological concepts in several ways. A teacher (1) might demonstrate the procedures, or (2) might use language to explain the procedures, or (3) might use language to describe the characteristics of the patterns produced in weaving (e.g. a pattern of diamond-shaped forms). The means by which the teacher represents weaving procedures and patterns may, in turn, lead children to particular kinds of goals, and, in turn, to particular kinds of representational forms associated with the weaving of topological relations. In our analyses of interactions and verbalizations, we compared the teachers' use of demonstrations and verbalizations, and we also looked at particular uses of language—such as representation of patterns in the weave as opposed to the representation of topological relations. Detailed coding schemes were developed to analyse the frequency and complexity of each of these modes of instruction.

Analyses of the videotapes revealed that the interactions contained very little verbal instructional content that made explicit in language the procedures needed to weave. No instruction ever included description of the visual characteristics of the patterns. Indeed, for both weavers and non-weavers, the level of complexity of the demonstrations was considerably higher than that of the verbal instructions. Though the demonstration complexity was higher, it still was typically incomplete. Teachers appeared to expect learners to make active efforts to learn on their own and they assisted primarily when needed.

The low level of verbal instruction complexity cannot be taken as an index of instructional quality. Indeed, learners formed goals and solution means consistent with the superordinate objective of task completion. All but three of the learners (each an inexperienced weaver) mastered the new weave. Furthermore, teachers adjusted their instruction appropriately to the prior knowledge that children brought to bear on the activity. For each weave, teachers assisted about 60 per cent of the weave attempts for the non-weavers whereas they assisted only about 25 per cent for the weavers. Finally, teachers provided instruction appropriate to learners' difficulties: for example, the correlation between the proportion of learners' errors that were topological and the proportion of weaves that contained assistance with topological relations (e.g. 'push the straw under'; 'It goes under'; 'Push it through') was strong (about .60). Thus, for learners who were less experienced and for any learner who had specific difficulties during the interactions, teachers assumed more of the responsibility for the weave, simplifying the learners' task.

The observational study points to an environment in which children's goals emerge with learners' and teachers' efforts to accomplish a successful tutorial interchange. There were three noteworthy results: (1) Verbal instruction is usually concerned with particular actions; rarely, if ever, is the complete five-component process of weaving the dandoca formulated. (2) Virtually all instruction is concerned with actions affecting topological relations, and not the characteristics of the static products produced. (3) The evidence from this interactional study is most consistent with a conclusion that the representational forms used to accomplish the weave are sensorimotor actions that have been learned as independent schemes such as folding under, using rectilinear sides as indices, pulling strands between adjacent pairs.

Further support for sensorimotor representation is provided by our second study,

in which we analyse the understandings children construct in the course of the weaving practice. As will become clear, the forms of knowledge constructed are flexible schemes that can be orchestrated intelligently in problem solving.

Study 2: Analyses of children's understandings linked to the practice of weaving

To gain insight into weavers' representations of topological relations and patterns, we created a battery of tasks and administered the tasks to 15 5- to 7-, 25 8- to 11-, and 21 12- to 15-year-old weavers.

Knowledge of the bico

Three tasks were designed to assess children's knowledge of the most widely produced traditional weave—the bico.

One task was simply an assessment of children's skilled performances and revealed that even the youngest children were capable of producing the bico, though the speed of production increased regularly with age.

Two additional tasks were assessments of the means by which children represent the bico in their weaving activity. There are two possible means by which children may represent productions of the bico: the pattern of topological relations produced by a coordinated sequence of actions, and the particular visual rectilinear patterns of intertwined strands which index each step of the process. To determine whether one form of representation was favoured, we examined children's ability to weave the bico with a material that did not provide the same kinds of visual/rectilinear cues—a very heavy wire that could be intertwined but not folded. Even with the quite different figural properties that emerge in weaving with wire, the large majority of children produced a homeomorphic relation of the straw weave, though the age trend shows that younger children had some difficulty, suggesting that they may rely to some extent on the rectilinear pattern that emerges with the straw. We then presented a bico that children had woven previously with straw and their own strange-looking wire bico and asked them if the two weaves were the same or different and to justify their judgement. Virtually all children who wove the wire bico correctly argued that the wire and the straw bico were identical and referred to their prior actions of weaving to justify their judgement.

Representing the bico in speech

The findings from the analysis of tutorial interactions suggested that weavers may have difficulty representing the process of weaving in speech. To test this, we asked child weavers how they would explain how to weave the bico to another child, and, to determine whether possibly adequate explanations might be simply memorized formulae, we asked children how they would explain how to weave if they turned the bico upside down—an operation that would require them to invert the spatial relations in speech. We then asked children to weave upside down and to explain again. We found that not a single child at any age group provided an adequate

explanation of the bico right side up, and many children did not even refer to the critical topological relations at all in their explanations right side up or upside down before or after completing their weaves. However, the majority of children in each age group succeeded in making the inverted bico. While children's ability to formulate the topological relations in speech were quite limited, their conceptual competence in inverting relations in action was striking.

The findings up to this point show that weavers display a remarkable facility at their craft at a young age. Further, weavers appear to appropriate action schemes such as folding under, pushing through, following the path of a strand as representational units that serve both communicative functions in tutorial interactions and problem-solving functions in weaving. The final analysis that we present addresses the question of the flexibility of these sensorimotor schemes: Are children merely learning sensorimotor action recipes for particular weaves that have very limited generality? Or, can weavers apply the topological knowledge that they generate in their practice to learn new weaves that they have never seen before?

Novel weaves tasks

To examine the generality of children's practice-linked topological knowledge in action, we presented children with three novel weave patterns one at a time and in counterbalanced order. The patterns were unknown in the weaving community. Each weave was presented with long extended strands of straw for children to continue.

Two contrasts were of interest for the novel weaves task. First, age groups of experienced weavers, 5 to 15 years of age, were compared for their ability to reconstruct the novel patterns. Second, the weavers' performance on the tasks was contrasted with two groups of age-matched non-weavers to determine whether the practice of weaving contributed to children's ability to reconstruct the novel weaves. One group was children from the same weaving community who were familiar with the craft of weaving, and the other group was children from a nearby urban centre who were less familiar with the craft.

The task was administered in two phases for each weave—an assisted phase and an unassisted phase. In the unassisted phase, which lasted for three minutes, the child attempted to replicate the pattern (without assistance). If the child completed the weave accurately within this time period, the task was considered completed. If the child did not replicate the weave successfully, children were presented with a fresh model of the target weave with extended strands, and they were asked to continue their attempt to copy the weave; if the child produced an error during his or her efforts, the interviewer intervened, corrected the child's error, and demonstrated the next correct fold while saying, 'Look how I do it, it is like this'. The intervention was a demonstration of the same sort we documented in the videotaped analysis of teaching interactions. The assisted phase was terminated after either the child made four errors or after five minutes, whichever came first.

Analyses of children's solutions revealed effects of age, weave complexity, and weaving experience. First, analyses of age differences in the weavers' solutions revealed a common pattern across the three novel weave tasks, though the weaves

varied in difficulty. The youngest children had the most difficulty in creating a weave that was homeomorphic to the original pattern, but with age children's ability improved. Participation in the weaving practice was associated with greater ability to produce a weave homeomorphic to the novel weaves. Non-weavers demonstrated less facility in constructing the homeomorphic weave than the weavers. Further, non-weavers did not generally benefit from the instructions whereas weavers and their peers did.

Conclusion

When experts were assisting novices in their efforts to learn a new weave, goals emerged that were dependent both upon the prior knowledge children brought to the practice and teachers' adjustments to learners' difficulties during the tutorial interaction. These adjustments occurred principally in the teachers' actions and less so in their verbalizations. In turn, learners' emergent goals were not linked principally to formulating activity in speech or identifying static patterns in weaves, but rather to identifying and deploying patterns of sensorimotor action forms of folding under, pushing through, and separating. In their efforts to accomplish these goals, we found that weavers constructed an ability to accomplish conventional weaves at a young age.

We also found conceptual developments linked to children's weaving activities. Rather than merely learning recipes for action patterns, children's knowledge of topological relations was generative, and increasingly so over age. On tasks involving the construction of inverted relations on the *bico* or in the construction of patterns homeomorphic with novel weaves, weavers were quite competent and their performance was considerably better than that of the non-weaving children.

We believe the findings documented here point to the importance of investigating the various possible semiotic forms that mediate teacher-learner interactions and children's representations in problem solving. While the renewed interest in speech as a privileged semiotic system unique in its properties to decontextualize learning has resulted in important new research findings (see, for example, Wertsch, 1985), we may have neglected other semiotic systems central to problem solving and the affordances that they offer. Indeed, in the study just reported, we found that sensorimotor action schemes constituted cognitive forms that could be distanced from the contexts in which they were learned. Evidently, speech is not the only form that enables the individual to appropriate and restructure knowledge generated in one context to solve problems in others.

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