CHILDREN'S MENTAL REPRESENTATIONS OF SMALL SCALE THEMATIC MAPS.

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Children's map schemata

Small scale thematic maps that use point symbols to show the location of economic activity (for example, Figure 1) are a common feature of school atlases. They have, however, undergone a considerable amount of generalization in their preparation and we know little about how school students make meaning from them.

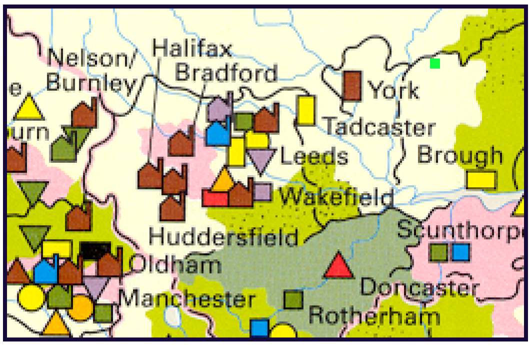

Figure 1
Extract from a school atlas map showing manufacturing industry in part of the UK.
(Source: Wiegand (1997) *The Oxford School Atlas*, p. 47)

Map structuring mechanisms that organise sensory input and retrieve information from long term knowledge representations have been termed *schemata* (Rumelhart and Norman, 1985). Schemata are particularly useful in that they enable us to depict knowledge acquisition in a more organic way than a linear hierarchy (of the sort advocated by Gagné, 1965) by using semantic networks that show relationships in many directions. Schemata can be conceived as nodes with links between them. The nodes represent categories or attributes of categories and the links specify possible relationships that exist between the nodes. Mental categorisation of new sensory information is influenced by potential relationships specified by the schema that an observer brings to bear on a situation - such as understanding a map. MacEachren

(1995) proposes that humans have both a general map *schema* and specific map *schemata*. Specific map schemata (such as those for road maps, topographic maps or weather maps) develop by modifying, expanding and filling in the details of the general schema. This happens in many ways, including formal teaching, observing and making inferences in the field as well as applying schemata from other domains. Whilst most map users have an intuitive grasp of the main principles of the general map schema, specific map schemata probably have to be learned. There appear to be few, if any, descriptions of specific map schemata but Pinker's (1990) elucidation of the conceptual structure of a bar graph (outlined in McEachren, *op. cit.*) provides a useful model for investigating what is seen when a map user 'reads' a map as well as a means of identifying what the user needs to bring to the map in order to understand it. His 'visual description' consists of nodes and links, with elements of hierarchy shown by arrows.

There have been two principal approaches to children's construction of knowledge. The first (Piagetian) position has been the dominant model of children's cognitive development in relation to their use and understanding of maps. The second (Vygotskyan) underpins the collaborative learning model adopted by the present study. The essence of Vygotsky's approach (Kozulin, 1986, 1990; Wertsch, 1985) is to treat human learning and cognitive development as a process that is culturally based. It is a communicative process, which is social rather than individual, whereby knowledge is shared and understandings are constructed in culturally formed settings. Much attention is paid to the role of talk as a medium for sharing knowledge and potentially transforming understanding. In the last few years there has been increasing interest in collaborative map learning. Leinhardt *et al*. (1998) used both a didactic and constructivist approach to children's map learning involving symbols, longitude and latitude and scale. In a further paper, Bausmith and Leinhardt (1998) attempted to analyse the reasoning of 12 students in undertaking this task. Students' success was influenced by the extent to which they were able to recognise the interconnections between the map elements. The notion of 'pupil as cartographer' in which the map user also has control over the content and appearance of the map is one that is almost entirely unfamiliar in UK schools. Evidence as to how school age learners construct and interpret electronic maps and about the nature of typical cartographic misconceptions and learning difficulties should enable us to build effective strategies for teaching and suggest appropriate models of curriculum planning. Only when we understand how young learners make meaning from maps can we approach real world problem solving using GIS-like tools with confidence in geography teaching.

Investigation

Using a simple software mapping tool, 50 pairs of school students were invited to solve seven cartographic problems involving point symbol generalization in order to identify their map making strategies. Participants were drawn equally from year 7 (age 11-12 years) and year 9 (age 13-14 years). A pre-task interview was conducted with each pair of participants in order to: 'situate' the map tasks in the context of an atlas-related activity; establish participants' understanding of legend language applied to thematic point symbol maps; and confirm participants' basic understanding of relevant general map schemata. Participants were then invited to resolve seven thematic mapping problems. Each successive task represented an increase in complexity through the addition of referents, extra themes and/or the addition of quantitative information. The tasks consisted of making thematic economic maps to represent a displayed factory distribution (the 'referents') on an overlay (which appeared to unroll across an overhead 'world view') by clicking and dragging symbols from the palette. The 'world' could then be removed, leaving the map as a representation of it. Symbols once in place on the overlay could be further manipulated to refine their positioning and a completely fresh start can be made by using a 'Put back' button. The screen presentation for one of the map tasks is shown in Figure 2.

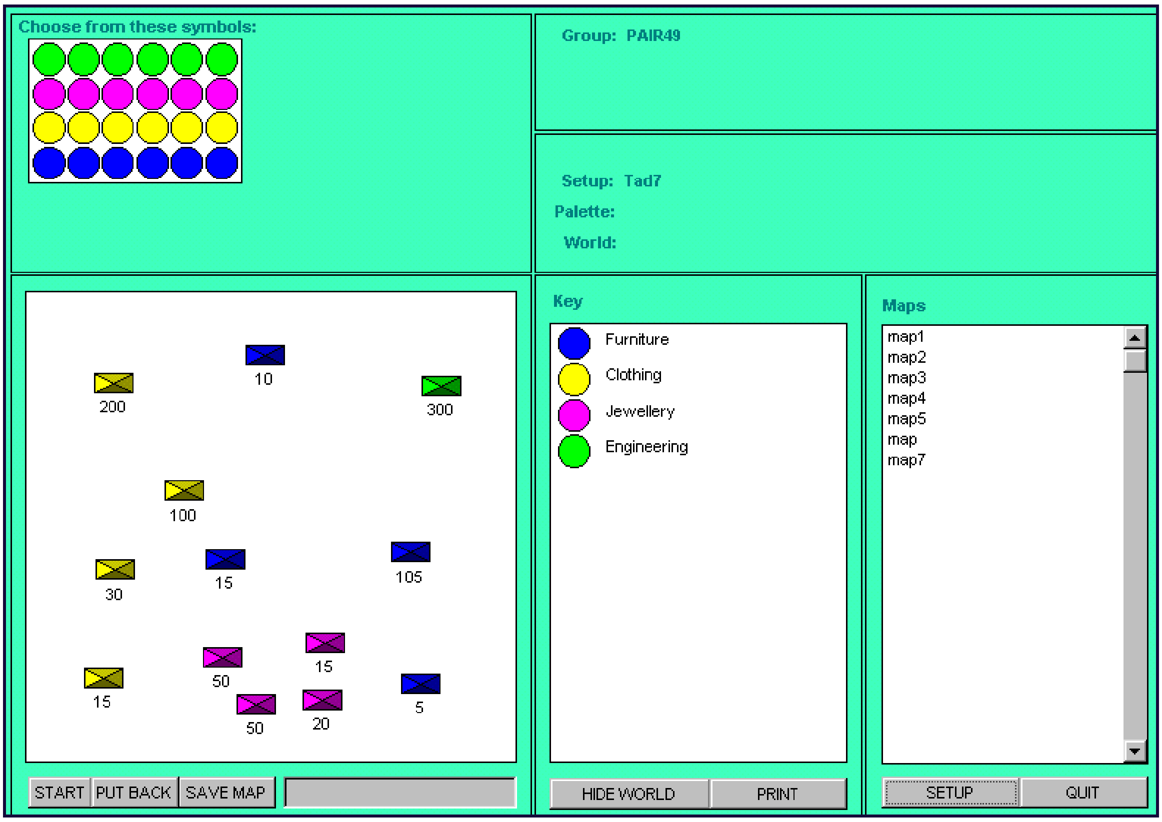

Figure 2
Screen presentation for map task 7.

A post-task interview was conducted with each pair of participants in order to: probe for further thinking about how thematic point symbol maps 'work' through open-ended questions; and provide some teaching input and 'closure' to the map tasks.

A map classification scheme was constructed (Figure 3) in order to identify the correspondence of each map to the following criteria:

- Did the position of the symbol(s) match in any way the spatial distribution of the phenomena they represented (the referents)?
- Were the symbols weighted towards the greater cluster(s) or numerical value(s) of referents?
- Did the symbols show equivalence and balance between distributions where there was more than one referent theme?

Category number	Name	Description
0	Non-nominal	Symbol(s) placed outside referent distribution
1	Nominal	Symbol(s) placed within referent distribution(s)
2	Single ordinal	Symbol(s) placed with respect to spatial distribution of one theme
3	Multiple ordinal	Symbol(s) placed with respect to spatial distribution of two or more themes
4	Single interval	Symbol(s) placed with respect to numerical values of one theme
5	Multiple interval	Symbol(s) placed with respect to numerical values of two or more themes
6	Ratio	Symbol(s) placed with respect to equivalent numerical values across two or more themes

Figure 3
Map classification scheme

Map outcomes

Table 1 summarises the classified map outcomes for each task, by age group. As the map tasks were progressive, not every map could be classified within the full range from 0 to 6. Grey areas in the table therefore show prohibited categories for each map. From Table 1 it can be seen that 11-12 year olds perform better on the map tasks than 13-14 year olds. The modal scores for map task 3, for example, demonstrate a shift in cartographic thinking from nominal to ordinal and for map task 7 from ordinal to interval. There is a significant difference in performance between year groups on map tasks 4 and 7 and a highly significant difference on map task 3.

Table 1.

Classification of maps by age group.

a) **Year 7 (age 11-12 years)**

	Map 1	*Map 2*	*Map 3*	*Map 4*	*Map 5*	*Map 6*	*Map 7*
0	2	2	1	0	0	0	2
1	6	5	18	12	12	4	0
2	17	18	6	2	1	12	0
3				11	12		11
4						9	2
5							9
6							0

b) **Year 9 (age 13-14 years)**

	Map 1	*Map 2*	*Map 3*	*Map 4*	*Map 5*	*Map 6*	*Map 7*
0	1	0	0	0	0	0	1
1	3	8	10	4	7	5	0
2	20	17	15	2	0	10	0
3				19	18		5
4						10	3
5							14
6							1

Analysis of discourse

Discourse analysis has been applied to map learning but in a limited way and with contradictory outcomes. The discourse of each participating pair was examined for its contribution to learning gains and conceptual change. The scheme used for this was based on *rhetorical structure theory*, in which the structure and hierarchy of ideas are represented through the identification of 'rhetorical predicates', which can be used to track the ideational content or structure of argument as it develops from one discourse participant to another. Such predicates include cause, consequence, condition, purpose, etc. which are used to develop argument by linking together factual propositions. A modification of Pilkington's DISCOUNT scheme (1999) was used in order to track the initiative taken by participants in exchanges and to identify patterns of exchange, enabling shifts in dialogue role to be investigated as well as the effectiveness of the dialogue in terms of learning functions. The effectiveness of particular styles of interaction could thus be examined through the tracking of discourse cues to specific rhetorical relations.

The data consisted of a total of 2 513 separate discourse 'moves'. Moves were coded according to their function. Using *inform* moves a participant makes observations and states facts about the map. *Direct* moves (which include suggestions and counter suggestions) are predicated by action. The task orientation of the map-making episodes made it likely from the outset that this would prove to be the largest category of recorded moves. *Direct* moves are unsupported by justifications or reasons; they are simply instructions or suggestions for symbol placement. *Reason* moves are declarative statements, which identify instances of reasoning learning activity. They include beliefs constructed as a result of the mapping task and generally provide justification or support for an identified strategy (e.g. 'Put a yellow symbol there *because there's a cluster of factories*'). *Question* moves invite a response which provides an explanation.

Each functional move category was qualified by a subcategory representing map schemata elements. These qualify the moves by drawing attention to the ideas employed in the search for a cartographic solution. The subcategory focus *denote* simply signifies or indicates the object under consideration. No cartographic idea *per se* is attached to this focus, it simply serves a nominative function in relation to the map. It characteristically appears in the transcript as an unqualified 'there', in conjunction with a pointing gesture. The focus *theme* refers to differentiation and/or equivalence of cartographic themes (i.e. the various industries to be mapped or the colours used to distinguish them). *Spatial distribution* moves refer to the spatial pattern of referents and symbols and the identification of singletons and clusters. *Value* moves refer to the numerical value of points in the referent distribution. There were relatively few instances where moves contained more than one ideational focus but where they did occur a rule-of-thumb hierarchy was established in which each of the following categories were assumed to subsume the preceding one: theme; spatial distribution; value. *Other* is a subcategory focus applied only to *reason*. This is a useful category because it helps to identify misconceptions and irrelevant or erroneous reasoning. In combination, these two dimensions (i.e. the functions of moves and the schemata elements) enable conclusions to be drawn about the way in which each pair collaborated verbally in the execution of the task and the ideas they deployed in arriving at a solution.

The discourse during task completion was generally expeditious and highly focused. Participants said more and engaged in more verbal interaction of a higher order as they completed each successive task. This may reflect the incline of difficulty within the tasks and the need to 'talk through' a solution. Younger children talked more and exchanged more conversational turns. It may be that the older children saw more readily what solution was required or that their discourse was more efficient in achieving it. It may also be that adolescents are characteristically more reticent in year

9 than in year 7. Surprisingly, there appear to be few references to this possibility in the discourse literature. Sustained interaction by pairs from either age group was rare and this may have been due to the strongly goal-oriented nature of the mapping tasks. The more demanding map tasks were characterised by greater symmetry in conversational turns. The most successful maps were those where discourse was most symmetrical.

Discussion

The findings reveal an association between the quality of maps produced and the characteristics of the discourse during their production. Higher order maps from older students are associated with *reason* and *question* discourse moves and *thematic* and *spatial distribution* ideational content. Higher order maps from younger students show an association with *direct* and *question* moves, but have no association with ideational content. The association between older children's discourse moves and success in the mapping task, therefore, appears to support Chi and Bassock's (1989) claim that students who are able to explain their choice of decision whilst solving problems are more successful.

All the children participating in this study appeared to be able to engage with the initial printed map extract at a lexical level yet, when their understanding was probed through a series of map making tasks, they revealed substantial misconceptions about how such maps represent the world. Generalising from the data presented here must be undertaken with caution but it does not seem unreasonable to suggest that perhaps one in ten of the younger and one in twenty of the older children have very little understanding at all of the principles on which small scale point symbols represent economic activity. They may believe, for example, that the symbols encircle the features they stand for. Perhaps half the younger and one third of the older children have weak understanding of how point symbology is based on both the spatial distribution and the value of their referents. Perhaps only one in twenty of (just) the older children are able to make meaning from the map in a way congruent with that of a professional cartographer.

There is, however, a very large range of understanding within both year groups. On the whole, the older children made better maps. Yet even among this age group there were substantial misconceptions and much evidence throughout of children operating at the limits of their understanding. There were also many instances of a mismatch between the maps made and the rationale provided for their construction. We cannot assume understanding on evidence of task outcomes alone.

Small scale economic maps of the type described here are likely to be most effective when map makers use a well-formulated schema to organise and represent the information and when young map users use a compatible schema to view it. Student learning gains could be expected to result from an enhanced understanding on both sides of both map making and map using protocols. Teachers and school students could benefit from greater understanding of cartographic principles and cartographers could usefully match design and representation to users' intuitive interpretation strategies. Although Gerber, Lidstone and Nason (1992) claim that we have 'no viable competency model of expertise . . for the domain of map reading', schema theory does appear to provide a potentially fruitful approach to achieving this mutual understanding.

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