PROGRESSION IN MAP LEARNING

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1. Introduction.

The notion that teaching should be based on progression is well established. It is a commonplace that good teachers should proceed from the known to the unknown, from easy to more difficult tasks and from simple ideas to more complex ones. However, little specific attention had been given to conceptual progression in the geography curriculum in the UK until the publication of a seminal paper by Trevor Bennetts (1981) identifying principles which could be used to guide curriculum developers. The following decade, leading to the inception of the National Curriculum in 1991, saw much discussion of the issues surrounding progression although many are of the opinion (e.g. Adey, 1997) that work by curriculum and learning theorists appears to have had little impact on policy makers. This paper attempts to look at some theoretical perspectives in relation to both epistemology (the nature of knowledge and skill) and child development (the way in which young learners acquire or construct knowledge and skill) and to provide some illustrative exemplars in the domain of map learning.

Some dimensions of progression in a cartographic curriculum

Progression is a feature of a cartographic curriculum which attempts to match its provision to the capabilities and needs of pupils. It is characterised by the content and structure of the programme of map skills and experiences, the range of maps and other resources available and the actual teaching that takes place. Progression refers to the advance in quality of pupils' attainment as they move through the school system. It is closely related to differentiation. This refers to the match between curriculum provision and the interests, experience and capabilities of pupils of roughly the same age. (these definitions have been adapted from Bennetts, 1996).

The challenge for curriculum developers is to match the increasing complexity of map learning activities with the maturation of pupils. This task can be conceptualised in the form of a ladder. One arm of the ladder represents children's maturation (their emotional, intellectual, physical and social development). The other represents increasing complexity of knowledge and skill as some maps are inherently more difficult than others and some map skills more demanding. The rungs of the ladder represent appropriate activities and tasks matched to pupils' capabilities and these build on prior learning. Although helpful in identifying the key issues to be addressed in curriculum planning the ladder model is a considerable oversimplification. In reality, learning is more unpredictable and serendipitous. Nevertheless this representation will be used to provide the structure of the following limited discussion of progression in map learning. First, some models of child development will be examined (I have restricted this to children's cognitive development) and then some approaches to subject structure. I shall attempt to illustrate these with map learning exemplars.

Models of cognition in childhood

Any consideration of progression has to be set against a background of models of children's cognition. Three paradigms (following Meadows, 1993) are reviewed here: Piagetian, Information Processing and Vygotskyan.

Piaget's work has been immensely influential. The central idea is that cognition is a form of environmental adaptation. It proceeds by 'assimilation' (whereby new information is related to pre-existing structures of knowledge and understanding) and 'accommodation' (in which the old structures are developed into new ones in the light of successive experiences). These two processes work together to enable individuals to organise knowledge into coherent systems. A beginning map reader, for example, may identify blue lines on maps as depicting water features. Subsequent experience with different sorts of maps reinforces this rule (assimilation) until a road atlas is used in which motorways are shown in blue. The 'blue line represents water' rule must now alter (accommodation) to embrace other phenomena.

One aspect of Piaget's theory is that cognitive development forms an invariant sequence of coherent and qualitatively different stages: sensori-motor; pre-operational; concrete operational and formal operational. It is this sequence which is relevant to the notion of curriculum progression. Thought within each of these stages is relatively stable across a number of contexts. Pre-operational thought is characterised by children beginning to use semiotic systems such as language (and map representations) but not yet being able to conserve, classify, seriate, co-ordinate perspectives, etc. Concrete operational children can do these things. They can recognise, for example, that the distance A to B is the same as the distance B to A, that if you describe a journey on a map as 'turn left, right, left' in one direction it becomes 'right, left, right' in the opposite direction. In the concrete operations stage children are able to classify map symbols into points, lines and patches and use reference systems which require the application of two or more criteria arranged in a series to locate an object. In formal operations (typically beyond the age of about twelve years) more abstract and integrated thinking is possible so that problems such as comparing distance on two maps at different scales can be tackled or identifying landforms from contour maps. Piaget's work on spatial cognition has been especially influential in geography education and his identification of topological, projective and Euclidean spatial thinking underpins the accounts of progression in map learning by Catling (1979) and Boardman (1983).

Those working within the information processing paradigm are primarily concerned with the mental processes involved in selection, representation, storage, retrieval and transformation of information. Many comparisons are invited with computer hardware. Atkinson and Shiffrin (1968) propose that the structure of memory consists of several stores: a sensory register, short term memory store and long term memory store. These attributes are possessed by children as well as adults, but control over memory changes with development and with learning. We build strategies that can increase the speed and volume of information transfer between the short and long term memory stores such as the use of mnemonics (e.g. Naughty Elephants Squirt Water to recall the cardinal points of the compass). Maturation means that less support is necessary for recall. Younger children, for example, may rely on an alphabet listing at the top of each page in order to find places in an atlas gazetteer (as more processing capacity is taken up with the list of unfamiliar names) whilst older children have less need for a legend on every page of the atlas as they can recall unprompted a larger selection of standard symbols.

The information processing approach also seeks to describe children's abilities and limitations and successive points in their development. Recognition, scanning, categorical perception, associations between modalities, events and pieces of information can all be observed in very young children but speed and flexibility improve with age and experience. On the whole we'd expect older children to be able to scan a world map and find Zimbabwe more readily than younger children. They may, of course, have more information (for example that Zambia is in Africa) but they are likely to be able to scan more rapidly, selectively scan for labels in upper case only (identifying country names) and discard those in upper and lower (settlements). They may give attention only to words beginning with Z, immediately discarding from their search words beginning with other letters. Younger children generally show less evidence of employing deliberately strategic approaches to tasks and have a smaller repertoire of strategies available. Note also that individuals do not always employ the best strategy (Simon) but frequently the most familiar one or that which is perceived to be most effective (such as lengthier map scanning rather than using the index). Some processes become more or less automatic whilst others require more conscious control. Much depends on the demands of the various components of the task. Young map readers, for example, may be quite capable of finding co-ordinates especially when freed from the conscious processing demands of numbers to identify grid lines and use instead colours and shapes.

Information processing models assume that there must be internal representations of information on which cognitive processes act yet the way in which we store spatial information remains unclear. A further problem is that we cannot directly observe cognitive processes but infer them from behaviour. This is often mediated by language and in the case of maps, by for example, the maps that children draw.

Vygotsky's approach to cognitive development differs from the Piagetian model and the information processing position in that it emphasises the prime importance of the social world. The heart of Vygotsky's theory is that cognitive development involves the internalisation of ideas and skills which have been learned socially from more competent partners (adults or other children). The child and more skilled learner interact, the more skilled partner providing the structured context within which the child may be able to achieve a successful outcome to a problem or task. Initially, the more experienced partner provides almost all the cognitive framework needed but through repetition the child undertakes more of the task until the 'scaffolding' provided by the other is no longer needed. The key theoretical construct is the zone of proximal development (ZPD). This cumbersome phrase refers to 'the place at which the child's empirically rich but disorganised spontaneous concepts meet the systemacity and logic of adult reasoning'. The ZPD is 'the distance between a child's actual development level as determined by independent problem solving and the higher level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (Vygotsky, 1978, p.86). In other words, before being able to do something on your own you are likely to go through a phase when you can do it with a bit of help. Vygotsky makes the point that this is a common, normal and important feature of human development. The weaknesses of spontaneous reasoning are compensated for by the strengths of scientific logic. Children 'appropriate' adult structures and are helped to learn adult-sanctioned solutions to problems. In this way they are socialised into the cultural norms of society and also, in relation to specific domains, into the ways in which expert practitioners approach problems.

According to Vygotsky, one of the central tasks for schooling is to bring the systematic and hierarchical structure of scientific concepts into conjunction with the concrete and unsystematic everyday concepts brought to school by the child. The boundary between these two types of concepts (probably more blurred than Vygotsky acknowledged) is an important one for geography teachers to explore, partly because so many 'geographical' words have both technical and vernacular meanings. A 'country', for example, is popularly used to describe 'a land' but also has scientific meaning as an independent nation state (perhaps described for children as 'a land with its own people and its own laws'). One of the ways in which teachers will bridge the gap between the two types of concepts is to define one in terms of the other (e.g. hectares may be defined in relation to the area of a football field).

The role of social learning in relation to maps has received very little attention until recently (Leinhardt, et al, 1998; Wiegand and Tait, 1999).

Approaches to curriculum structure

What constitutes map knowledge and map skills can be classified in many ways. It is common for teaching and learning activities to be categorised under headings such as perspective, symbols, scale, direction and distance even though it is very difficult to isolate each of these aspects of map understanding in any particular activity. Similar classifications can be made of map skill, such as reading and interpreting maps, spatial problem solving, wayfinding and map drawing. The variety of maps themselves also provides some dimensions which could be used in creating a programme of map learning: topographic, thematic, topological transformations, maps for special purposes as well as the range of scales from world maps to large scale plans.

Some of these attributes of maps and the nature of map knowledge and skill in themselves suggest elements of progression. The process of making sense of a map, for example, has been described as sequential, involving detection of symbols, discrimination between them, identification of their real world referents and then interpretation of them in combination with each other (Keates, 1982). With this in mind, a teaching sequence might be constructed involving for younger children the use of maps employing fewer symbols with strongly contrasting shapes and colours standing for familiar features of the real world and progressing to maps requiring greater visual acuity and representing more abstract phenomena. Some apparently inbuilt elements of progression however appear illusory. In the UK it is customary for primary school teachers to begin geography teaching with the immediate locality and progress to more distant places and so map work with young children is more likely to start with the use of large scale plans and move later towards those of a smaller scale. However, there is no reason why children from a very early age should not be at least as familiar (and perhaps more so) with the globe or country map as with a map of their own locality. Starting with the globe and zooming in is as legitimate a strategy for progression as starting with the locality and zooming out.

Adey (1997) provides a very helpful conceptualisation of curriculum progression which can be adapted and applied to maps. 'Conceptual complexity' is the key dimension of a hierarchy of knowledge and skill learning but other dimensions must be considered too. In relation to maps, children have (and need to acquire) both breadth and depth of experience at each level of their development. Consider for example a seven year old boy. This individual owns a picture atlas and can recognise the names and shapes of many countries both on the world map and from the separate country pages. He associates from the picture evidence some characteristics of place. For example Canada has maple trees and ice hockey. He has access to a globe at school. He knows that it is a representation of the Earth and can identify his home country on it. He has been to a theme park and was able to use the map provided to navigate to the toilets and souvenir shop. He is able to draw a map of the journey from home to school. The map is limited in what it shows but some significant features on route are identified. He can look up the street in which he lives using the index of a streetfinder map and find the street on the appropriate page using the alphanumeric grid code.

The level of conceptual complexity in this case is, naturally, rather low and characterised by absence of conceptual links between the facility the individual possesses in relation to each of these cartographic artefacts. The artefacts themselves are somewhat random although perhaps typical. They might have been replaced or been added to by: a road atlas, a plan of the shopping mall, a computer game employing a 'view from above' or a local walking map at a scale of perhaps 1:25000. Breadth of experience is represented here by the variety of maps encountered and depth by the quantity and type of activity undertaken in relation to each. Breadth and depth together form a planar surface which describes the total amount of map experience an individual has. Adey acknowledges that these two dimensions offer 'a far from adequate account of the development of understanding' (Adey, 1997, 370) and that the picture is more akin to a web in which knowledge and skills are woven into a conceptual network.

Note that on the breadth-depth plane there is a limit to the way in which progression can be achieved. It makes no difference whether you learn about Canada from a picture atlas map before or after you learn about Brazil and in learning about how your locality is represented on a map of scale 1:25000 it doesn't matter whether you learn to identify some point symbols before others. But you need to have had experience of both before you are able to understand some aspects of symbol generalisation and scale. So, although there is little on this planar surface which defines progression other than 'doing more', it is important in enabling us to build a balanced cartographic curriculum incorporating a variety of maps (selected for scale, content and style) as well as what it is we expect children to be able to do with them (such as locating places, finding the way, looking for patterns). The third dimension to Adey's model is 'conceptual complexity'. This is visualised as a dimension on which successive breadth-depth planes as the one described above are stacked. Each successive plane represents higher order cartographic thinking, perhaps characterised by involving several sources and manipulating simultaneously a number of aspects of a problem involving application of symbols, scale, direction and distance. Adey's conceptualisation of curriculum progression is similar in many ways to that of Bruner (1960) who used the notion of a spiral in which learners would revisit at a higher level concepts and skills encountered previously.

Bruner (1966) was much concerned with the way in which individuals translate experience into mental models of the world. This was seen as a three tier process of representation in which intellectual growth depends on the individual's ability to internalise events. In the first 'enactive' system of representation, children engage in physical action, directly experiencing the environment and manipulating objects in it. In the second, 'iconic' system, children use objects to stand for others in the real world. In the third, 'symbolic' system, abstract symbols such as language and mathematical notation are used as forms of representation which enable individuals to hypothesise, speculate, predict and extrapolate.

This can be illustrated by a typical simple teaching and learning sequence with very young children. The teacher takes the children out on a local walk. They talk about the houses, shops, roads and cars they see. They pass the fire station, see the shiny red fire engines, hear the sirens and watch the fire fighters slide down the pole. Back at school they create a town scene using blocks. The red block stands for the fire station. The children 'drive' a model fire engine through the streets made by the spaces between the blocks. Their teacher then shows that by drawing around the blocks on a large sheet of paper the model town can always be reconstructed in the same way. By colouring in the spaces vacated by the blocks the sheet of paper alone can be used as a representation of the town. This map can be used as a tool to think with, for example to solve problems such as finding the shortest way from the fire station to a particular house. The progression in this teaching sequence clearly leads the children from direct experience to symbolic representation.

The illustration above is concerned with what learners do in relation to understanding maps. A contrasting approach is based on the structure of knowledge. Gagné (1965) identified an important kind of relationship in subject matter - that of 'learning prerequisites' enabling intellectual skills can be arranged into a hierarchy. Gagné's contribution, highly influential in programmed learning and task analysis, was to identify the order in which concepts could be presented to students in terms of the subconcepts that are logically prior. Course content is best sequenced in such a way that the prerequisites are always taught before the skills for which they are a prerequisite. Thus:

Higher order rules require as prerequisites:
Rules, which require as prerequisites:
Concepts, which require as prerequisites:
Discriminations, which require as prerequisites:
Basic forms of learning, associations and chains.

Prerequisites for understanding map scale, for example, would include being able to measure with a ruler, use units of measurement, relate these to the real world, understand ratio, compare measurements on the map with those using the scale bar, etc. A practical difficulty with this approach is that it is difficult to know when enough has been learnt of the subordinate concepts before proceeding to the higher order ones.

Learning prerequisites though are not the only type of relationship between elements of knowledge that facilitate learning. Ausubel (1968) advocated initiating instruction with an overarching principle and that successive teaching would consist of successive differentiations introducing more detailed and specific knowledge within the general ideas. Children might learn, for example, the general idea that symbols can be points, lines and patches. They might then examine, say, lines more closely and learn that they can vary in width and colour and be solid, dotted or pecked. They can identify which lines are used for what purposes on a map and look for principles that might govern their differential application.

Reigeluth's (1983) elaboration theory attempts to integrate the approaches of Gagne and Ausubel by providing a set of macro-level models that could be used to aid curriculum design. Part of the theory examines ways in which subject matter can be divided up in order to reveal superordinate, co-ordinate and subordinate relationships between ideas. There are a number of types of relationships that could be applied to the cartographic domain. For example, there are relationships of 'kinds'. These could be illustrated by a branching taxonomy of maps (in which, for example, land use maps are a sub-set of choropleth maps, which themselves are a sub-set of thematic maps, etc.). There are also relationships of 'parts' which might be 'topic' or 'aspects' of map understanding such as symbols, scale, perspective, orientation, etc. Some conceptual relationships can be shown in the form of a matrix, for example that between type style and purpose as commonly found on atlas maps. Other relationships in map learning include procedural structures, i.e. how to do things such as find where you are on the map, align it with the compass, identify landmarks, match intended route on the map to the real world, etc. Other types of conceptual structures include theoretical ones, which show change relationships among events, for example exploring what happens to the area depicted and the implications for symbology when the scale of a map is changed. Reigeluth's elaboration theory of instruction has been applied with that of Merrill's (1983) Component Display Theory (CDT) to the development of hypermedia learning programmes. CDT is a set of prescriptive relationships that can be used to guide the design and development of learning activities. It assumes some degree of learner control over both content and strategy. CDT classifies learning along 2 dimensions: content and performance. There are three performance levels:

- *Remember* is the performance requiring the student to search memory in order to reproduce or recognise some previously stored information
- *Use* is the performance that requires the student to apply some abstraction to a specific case
- *Find* is the performance that requires the student to derive or invent a new abstraction

and there are four content categories:

- *Facts* are pieces of information like proper names, dates, events, etc.
- *Concepts* are groups of objects, events or symbols that share common characteristics and are identified by the same name.
- *Procedures* are an ordered sequence of steps necessary to accomplish a goal, solve a problem or produce a product.
- *Principles* are explanations or predictions of why things happen in the world. They are cause-and-effect or correlational relationships that are used to interpret events or circumstances.

These two dimensions can be combined in a matrix. Table 1 illustrates such a matrix by showing, in each cell, performance levels for four levels of content. (In order to illustrate the scope of the framework an example is chosen of a higher order application of map knowledge and skill).

Find		Compare a set of map projections and classify them according to whether they are conformal or equal area.	Plot a Great Circle route on a Mercator map.	Explain why the Mercator projection should not be used for maps of land masses in high latitudes.
Use		Which of these map projections is a Mercator?	Calculate the exaggeration of the 60° parallel.	Select a suitable map projection for navigation.
Remember	When did Mercator publish his map projection?	What properties does a conformal projection have?	What is the formula for calculating the amount of exaggeration of the length of any parallel?	Explain how a cylindrical projection is constructed.
	Fact	**Concept**	**Procedure**	**Principle**

Table 1: Content and Performance Grid for Map Projections.

Conclusions

This review has attempted to briefly analyse two determinants of curriculum progression: the development of children's cognition and the structure of cartographic knowledge. Further research in the field of children and cartography ought to enable us to: identify those aspects of map experience which are worth developing; select skills, concepts, applications which are most useful; analyse what is involved in understanding and skill; and identify characteristic patterns of children's understanding and misunderstanding of maps and their uses. Much work remains to be done however in order to convert these theoretical perspectives into an effective and practical cartographic curriculum for young children which can be operationalised by non specialist teachers.

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