Learning Support using Knowledge Structure Maps

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Abstract:

This paper considers individual learners working alone without support from a teacher to provide guidance and advice on learning approach. Learners may have access to a wealth of material but may be faced with other problems such as material selection, planning a learning strategy, maintaining motivation and sequencing learning sub-goals.

Knowledge Structure Mapping is a method designed to produce a visible map of individual knowledge components comprising a study. These components or map nodes are linked by lines that show learning dependency. The map shows clearly the pre-requisite knowledge needed in order to progress. Knowledge Structure Mapping has been used successfully as a Knowledge Management Support mechanism for several business centred projects and several others in more topical knowledge areas. One very large UK manufacturer has adopted the method as part of its preferred Knowledge Management strategy.

The paper shows that Knowledge Structure Maps can be used as organised indices to learning material. It is proposed that the map structure can provide much needed support for learners from an information access and learning strategy perspective. Properties of the learning scheme based on Knowledge Structure Maps are discussed within the context of the difficulties faced by individual learners. A format for the information and appropriate access control to help to guide the learner through the learning task are also proposed. It is recognised, however, that the method could also be used to index other appropriate learning material as long as necessary guidance can still be provided.

Implementation of several trial systems using the approach described is discussed. Amongst issues to consider are user interface, system accessibility and the development overhead for a particular module.

Finally, results from a very restricted trial, offer encouragement that the approach has merit and that learners are likely to experience many of the proposed advantages.

1. Problems Faced by the Individual Learner:

The opportunities for an individual to make personal decisions about what to learn and then take charge of their own learning are increasing rapidly. Individuals could always buy books (always in more recent times that is) to learn things themselves but this requires commitment, approach or method and often experience and practice at learning. The addition of other media such as audio tape, video and television has followed but the issues of dedication, method etc have not changed. The internet is leading to an explosion of opportunities to learn but the would be learners task is made more difficult because of selection, validation and simply, truth. More recent promotion of learning options tends to neglect to point out that learning can be hard work just like physical training for a sport may be.

1.1 Learning alone:

It is not possible in this paper (or probably in even one dedicated paper) to discuss all of the issues faced by an individual learner. It is worth considering some of the main points however.

Hogan (Hogan 1998) discusses the different types of learners that may achieve some autonomy in different ways. The Building Tool Room is a web site created by "New Horizons for Learning" that adds to the debate about the issues faced by the individual learner by discussing learning styles and the wealth of information that has been written on this topic. Bork (Bork 1994) discusses the meaning of the term distance learning and pays particular attention to how this affects the delivery of learning. Heron (Heron 1993) argues for autonomy in learning, which tends to suggest that there may be more reasons to learn alone than being forced to do so.

For the purpose of this paper we will take a simpler look at the actual issues that a learner may face when confronted with a desire to learn and little else. One thing in the learners favour is the availability of options such as books, audio, video, the internet etc. This also adds to the learner's problem by presenting options without the methods to evaluate which is best for the purpose.

Once the learner can identify a source of material it may be difficult to identify just what needs to be learned. Personal experience has shown that some lectures are coloured by a lecturers personal tastes and particular expertise and experience even if these elements are not particularly relevant to the learning goal. Many authors are no less guilty of this. How can a learner separate what needs to be learned from what is presented?

The next problem that the learner may face could be planning a learning strategy. This may involve identifying logical learning progression paths, creating a varied and therefore interesting learning programme and finding a way of keeping track of progress.

Clearly, there will also be the issue of motivation and engagement. There has been considerable discussion concerning the level at which people learn. Passive reading is known to be much less effective than active engagement. In addition, motivation can wane after a relatively short period of newness and enthusiasm. This is often caused by an inability to detect progress, particularly in the early stages of a learning programme.

Learners may not always want to follow a learning path from start to finish in a methodical way. Sometimes a learner may want to know about the final learning goal right at the start even though they cannot appreciate the topic in any substantial way. This should not stop them from getting some answers or a simple summary though.

The individual and distance learner faces many problems. There are however also many advantages for the learner and for society in helping to overcome these problems.

1.2 Giving support:

If an individual learner is to be supported, the support must address many areas of life but also several areas that relate directly to the learning task. The needs of the individual learner include:

- Access to learning materials
- Strategies for learning
- Time to learn
- Advice on what to learn
- Feedback on progress
- Involvement and interactivity

The items listed above are typically the things that would be provided in a more traditional learning environment. Someone else, a trained person, would manage the learning process leaving the learner to get on with learning. For the distance or individual learner, these tasks must be accessed remotely or solved by the learner.

Accessing materials may not be a great problem, although it is for some, but accessing the best or the right materials may be more demanding.

There is not enough support given generally in teaching people the best strategies for learning or how to learn. Yet this is a crucial element in the creation of a society that sees learning as a lifelong experience. This aspect of learning should be addressed at school to equip people with the ability to learn later on.

Many think that finding the time to learn is the biggest problem. This may be a real problem or it may emerge from a general inability for most people to effectively manage their time. Time management is another area of knowledge that could be addressed earlier in life to equip people with the capability to continue learning later.

Once learning begins in an area that may be interesting or an area of need for employment for instance, initial enthusiasm can soon be replaced by a lack of direction. What to do next and what order to do things in can make a very significant difference to the size of a learning task.

Learners will usually want to know how well they are doing but they often know this anyway. This sort of feedback is usually driven by other people and organisations that see assessment and measurement as the core, rather than learning. Learners may simply want to look back and see how far they have gone just as people like to do when walking up a hill to some goal at the top. Learners also want to know how far there is still to go and have they got half way yet. This is more like the feedback that learners actually need.

Involvement and interactivity can be difficult for a distance individual learner. Some programmes of learning can use home experiment kits. These can be very effective but a more generally applicable approach is to challenge the learner and get the learner involved. One problem with books and the written word in general is that too many people simply believe what they read. Individual learners need to be helped to ask questions about material using terms such as ‘why is it like that’ and ‘what would it be like of this were not so’.

These are the sort of things that support the learning task more directly for an individual learner.

2. Knowledge Structure Maps:

The term Knowledge Structure Map (KSM), described in (Gordon 2000), is used to attempt to separate the more general term Knowledge Map from the idea used here. Knowledge Map (KM) is used to describe a variety of things including an index of who knows what, a concept map, a mind map etc. One may expect that a Knowledge Map would be a pictorial or diagrammatic representation of an area of knowledge with nodes and arcs having specific meaning. A Knowledge Structure MAP is not a map of knowledge, it is a map of the structure of human knowledge that shows how that knowledge is likely to be acquired by a human expert. A KSM does not in itself contain any knowledge other than information about its structure.

Knowledge Structure and Learning Dependency

In this work, the term 'knowledge structure' is used to refer to knowledge items or labels that are linked together based on their learning dependency. The example in figure 1 illustrates this point.

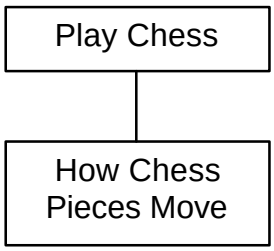

Figure 1: Learning Dependency

Figure 1 illustrates that if someone knows how to play chess then it is assumed that they must already know how chess pieces move on the chessboard.

2.2 Learning Dependency

The example shown in figure 1 takes a simple look at learning dependency by showing that in order to know one thing assumptions about prior knowledge exist. This particular example can be expanded to show more of the knowledge that is prerequisite to the knowledge of playing chess.

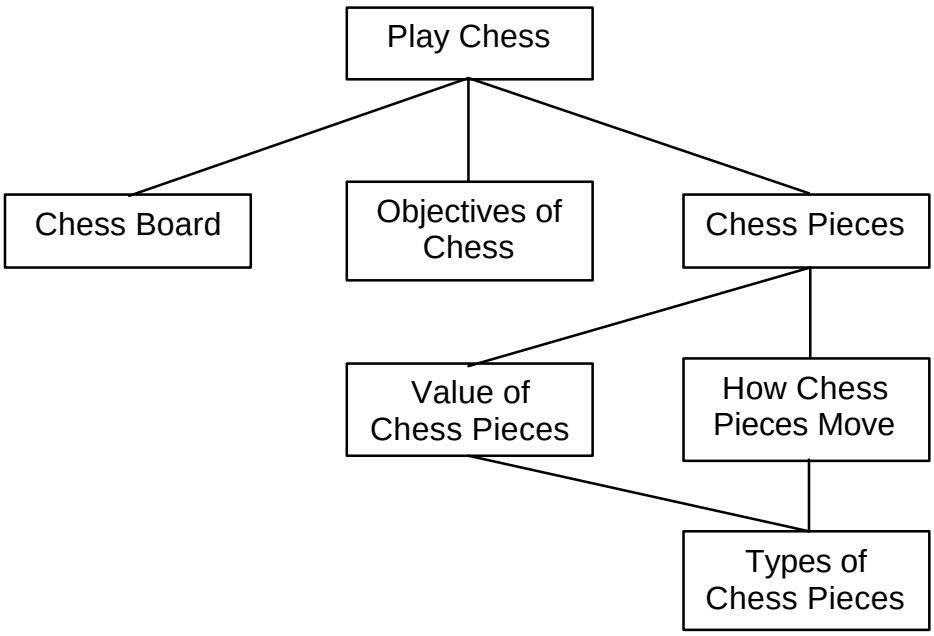

Figure 2: Chess in more detail

Figure 2 considers more of the learning dependency that exists within the knowledge of playing chess. It is still not complete because it misses important areas such as strategy. The interested reader may like to produce a more complete version of the knowledge structure map of chess organised by learning dependency that includes knowledge about strategy etc and expands the areas shown.

In figure 2, there are three knowledge items that are shown as necessary prerequisite knowledge of chess playing and the original prerequisite from figure 1 is not one of these. The knowledge of how chess pieces move is now seen as a necessary prerequisite of the knowledge of chess pieces. This knowledge is seen to rely on a prior knowledge of the value of chess pieces as well. The map shows that both 'value of chess pieces' and 'how chess pieces move' relies on a prior knowledge of the types of chess pieces.

2.3 Reading a Knowledge Structure Map

There is little new in the ideas behind a KSM other than the work carried out at AKRI (Applied Knowledge Research Institute) makes the idea more explicit and applies construction rules more rigorously. In some senses, all educational programmes use the idea to break study up into semesters and years and lecturers may break each part up into logical learning goals. A KSM is generally more detailed, the ideas of learning dependency are applied more rigorously and the main goal is the visualisation of a knowledge structure

The result of this is that a learning task can be made clear by using a KSM. The map will clearly show the learning goal, it will show where to start and it will clearly show the paths to be taken and provide answers to questions such as 'why is it necessary to learn this?'.

Maps are easy to read. Each node represents a piece of knowledge and the label in the box is the name of this knowledge. Links or arcs between nodes are unidirectional and always mean the same thing. A link shows that it is necessary for a person to know a particular piece of knowledge before it is possible for that person to have a full and detailed understanding of another piece of knowledge. A KSM is

usually constructed vertically, starting with the main or complex knowledge area at the top. Nodes linked to and below this node are essential prerequisites of that knowledge (figure 2).

2.4 Previous successes in the use of the KSM

Since 1998, the main applications of KSM have been in business and have been associated with the knowledge management domain. In this work (Gordon 2000) a KSM becomes the central component of a methodology collectively called Structural Knowledge Auditing (SKA). The motivations for this work are to provide managers with a clear visualisation of a human centred knowledge resource and also provide information about that resource so that appropriate action can be designed to protect, develop or in some other way enhance this resource. Successful projects have been carried out in large multinational companies, Small to medium Size enterprises and more diverse areas such as retail and leisure.

Successful means that the projects have lead to actual advise to develop the knowledge resource and have satisfied the primary goal of creating a clear visualisation of something that has high value but was previously invisible.

One large multinational has now adopted the methodology as a central component in its business knowledge management strategy. The KSM itself, sits at the core of this methodology but it can be used in other areas.

3. Creating a Learning Support Environment:

The way that a KSM is constructed means that it is highly relevant to a learning environment. In particular, once the map is made available it can be used or read by a learner with very little practice. The map structure makes learning support information directly and clearly accessible.

3.1 The relevant components of an SKA based KSM

In previous work, KSMs have contained information in the form of parameter values, for each node on the map. This is an essential part of the process of providing information that can support managers as they attempt to manage the knowledge resource. A complete project for business would concentrate on a report that contained recommendations intended to develop or protect the knowledge resource. The report would draw on information from the content of the map (the nodes), the way the nodes are connected (learning dependency) and parameter values elicited as the map layout is elicited.

However, to create a map that is useful in the learning environment it is just the knowledge nodes themselves and the connectivity or learning dependency structure that are important. A clear map showing meaningfully labelled knowledge nodes and providing structure that advises on how the knowledge should be explored by a learner are the key elements in this application. These are the elements that provide both access to the learning material and a supportive and informative learning framework for the learner.

3.2 A supportive Learning Framework from a KSM

The nodes on the map provide access to learning material that allows the learner to acquire the particular piece of knowledge selected. The map itself provides support for the learner in different ways. The map shows the learner :-

a) Where to start learning:

b) What to learn next:

c) Alternative learning paths:

d) What the size of the learning task is:

e) How much has been learned up until now:

f) How much there is still to learn:

g) Where learning is going:

h) Why am I learning this:

i) More about the learning task:

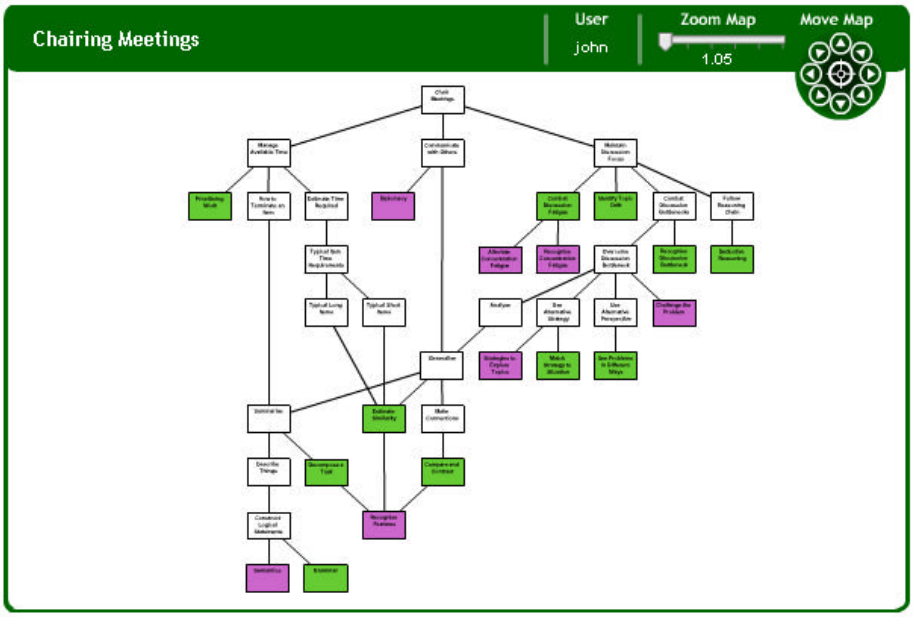

Figure 3: Screen from Chair Meetings map

Figure 3 has a colour code to assist the learner. Most of the knowledge nodes are clear indicating that they can be accessed for clarification purposes and general inquisitiveness (g, h and i above). The top node is usually the name of the learning task but also indexes to information (g). Nodes coloured green are either at the bottom of the map or supported by nodes that have already been fully explored (a, b & c above). Nodes that are coloured purple show items that have already been fully explored (e). The combination of clear and green nodes shows how much there is still to learn (f & d).

The map then serves as index to learning material and a straightforward yet comprehensive support environment for the learner.

3.3 Embedding Information within a KSM

Information is accessed by selecting a knowledge node. In the current system, this information is contained within the package and has been written for the particular application. This need not be the case however. Selecting a node could easily link to any relevant learning material. The only issue affecting implementation of this learning framework is that some indication that the material has all been successfully accessed is required in order to guide the learner to the next sub goal.

3.4 Using a Conversational and Challenging Learning Strategy

Learning material has been specifically written for the current experimental application. Figure 4 shows a section of the map (zoomed in) and a node that has just been studied called 'Compare and Contrast'.

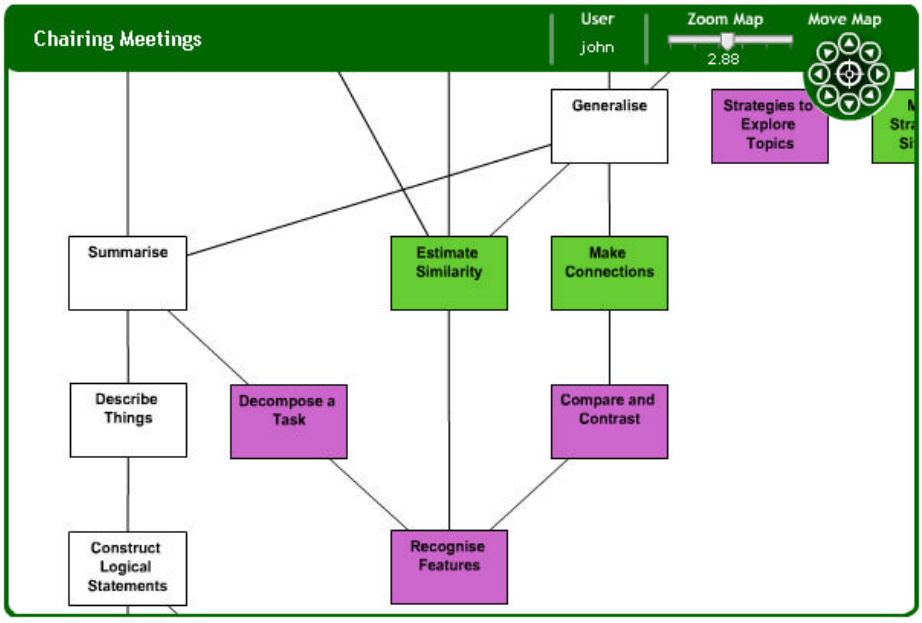

Figure 4: Zooming in to a learning task

Material at this node is quite brief and serves as a good example. The material is in three parts. There is some graphic support that is intended to help the learner to think more deeply about the issues. These are shown in figure 5.

Figure 5: Images from 'Compare and Contrast'

When the node is selected, an initial explanation is provided, shown below.

> ## Know how to match and compare features from several entities and identify similarities and contrasts of form or function.
>
> Some things would be easy to compare. Such things are similar things such as a nail and a screw. Comparing and contrasting dissimilar things such as a screw and a Wellington boot is more difficult. A good approach to this would be to select some properties that are applicable to each item. These could include, material (made of), size, flammability, water resistance etc. Some properties may not provide useful information but others could be very useful.

The third part of the material available from this node is the part that is only available to the learner that has completed the prerequisite nodes. This material is usually written in discussion style.

> ## Good ways to compare and contrast things include:
>
> **Using properties of the sort outlined in the explanation.**
>
> *This approach is valuable if the objects are so different that it is hard to make a start. The problem with this approach is that there may be many potential properties to compare but only a few of these may be interesting comparisons.*
>
> **Compare functionality.**
>
> *The use that things are or can be put to could form the basis for some very interesting comparisons. For instance, could the objects be used as doorstops? This sort of strategy is often used to promote creative thinking in people.*
>
> **Consider the ownership of objects.**
>
> *This is another different approach that could prove useful. Objects may be very different but they may typically be owned by the same sort of person and may be unlikely to be owned by others.*

This conversational material is not always as straight forward as the example shown above. The material below is from an area called 'challenge the problem' and extends the style in a more argumentative way.

> ## When should a solution or explanation etc, be challenged?
>
> **Every offer in a discussion or debate should be challenged; this is part of the debate process.**
>
> *If this were true it would take a long time to make any progress. Clearly only certain things should be challenged.*
>
> **Challenges should be made where the reliability of the source of the original statement is questionable.**
>
> *This is true but for the sake of a harmonious meeting, diplomacy should be used.*
>
> **Challenges to previous assumptions that have lead to problems with progress should be made.**

This is a useful strategy. Sometimes the difficulty with this is identifying the previous position that has caused the problems and therefore needs to be challenged.

Solutions or information that has considerable and serious implications should be challenged.

This is true for all practical purposes. It is not strictly true from a pursuit of knowledge perspective but decisions that may for instance lead to great expenditure should be challenged and also the nature of the problem that lead to the decision.

The style is intended to encourage the learner to think about the issues raised rather than to simple attempt to absorb the material.

4. Implementing a web based Learning Tool

Development of the idea of using educational media within the framework of a Knowledge Structure Map has been maturing over several years.

4.1 SKATMedia : embedded media experiment

A prototype system, SKATMedia, was developed in 1998 as an experiment into the possibilities of embedding knowledge, in various digital formats, into a Knowledge Structure Map. As such it extended the original SKAT system, which had been developed in house using Asymetrix Toolbook, a multimedia-authoring environment for developing Computer Based Training materials. It featured a variety of different media including video clips, a 3D environment rendered in VRML, emergent technologies such as the Microsoft Agent and a simple Expert System.

Toolbook proved to be an adequate environment for putting together a prototype system that could help capture the knowledge structure and explore some of the possibilities for embedding media, but ultimately it would prove to be unsuitable for developing some of the more intelligent, advanced features that are part of the tool as it is today.

SKATMedia was a useful first step into the possibilities offered by embedded media, but it relied too heavily on 3rd party plug in software for its operation. Some of these have proved victims of changing trends and fashion, for instance the Livepicture player needed to view a panoramic video is no longer available.

Development continued on the auditing Tool in LISP so no real development took place on the digital media/learning tool until the opportunity came up in the autumn of 2001 when a need for training materials for a Structural Knowledge Auditing course arose. The emphasis in development moved away from exploring embedded media and refocused on providing a user controlled learning experience.

4.2 SKALE: A CD ROM Learning Resource

Winter/Spring 2001/02 was spent developing a prototype CD-ROM based system intended to help learners to understand the process of Structural Knowledge Auditing. Developed in Macromedia Director, the system encompassed 127 distinct knowledge nodes and the support material was in excess of 50,000 words with over 100 related embedded images. This system (SKALE: Structural Knowledge Auditing Learning Environment) was generally perceived by the small (10) group of learners that used it to be a step in the right direction, although operationally it performed very slowly on users machines.

This was mostly due to the number of nodes (127) involved and the time the program took to check the status of prerequisite nodes. Users also had problems with the fixed screen size of 1024x768 pixels that was unviewable and unusable with smaller screens. We also wanted to trial the system with more users than the initial 10 so needed a method of distribution that could reach a wider audience without the need to mail CD-ROMS.

4.3 SPIKE: a world wide web Based Trial system:

The World Wide Web seemed to offer wider and more flexible distribution opportunities for trials of further systems than did CD-ROM so it was decided to concentrate efforts into developing a browser based version of the tool. The name was changed to SPIKE (Structural Prerequisite Interactive Knowledge Explorer) to move the emphasis away from Structural Knowledge Auditing and allow us to work towards a more generic reusable "shell" that we could use for any knowledge domain.

Content nodes are now in HTML format that means that in turn, additional modular content in terms of web deliverable media (audio, video, Flash etc.) can be embedded. The modularity of these content nodes increases ease of maintenance and offers more scope for reusability of content.

The vector graphic capabilities and improved programming language features offered by Macromedia Flash MX coupled with the ubiquity of the Macromedia Flash player across the world wide web (502,811,580 downloaded as of January 21, 2003) makes it a excellent choice for developing Knowledge Structure Map based navigation interfaces. Flash MX also has extended capabilities for developing rudimentary user profiling with the introduction of Local Shared Objects. The original CD-ROM version of the software was developed in Macromedia Director that has a similar programming language base to Flash MX so the transition was reasonably straightforward.

4.4 Further ideas for SPIKE

The development process for an individual SPIKE map is still very labour intensive. Further research and development on the learning tool could explore the possibilities of dynamically building a map from information exported from the auditing tool, rather than the "hand-built" approach currently employed. Another area of exploration could involve developing an "empty" knowledge structure map, that learners could populate nodes with meaningful content themselves. This approach would put the emphasis on a learner's research skills and would therefore be more appropriate for higher levels of study.

5. Initial Feedback and Future Development

Informally, people that have been shown this system and the ideas that underpin it are very enthusiastic. It is realised however that this does not mean that the system will really match the claims made in this paper. At the time of writing we have received a few objective feedback reports from people that have used systems, As stated above, these are primarily from two sources, an initial SKA training course and a more open web based pair of example systems.

5.1 Feedback from a CD based SKA Training tool:

Some general observations from 4 feedback forms include:

> "Very useful to be able to explore the knowledge area"
>
> "Very valuable to challenge statements that may be wrong"

"Agree with the control of information access in the system"

The section of the form concerning overall impression of the learning framework was probably the most positive set of responses. These questions were:

- **How much did you like the idea of a knowledge map?**
- **Did you find the knowledge map itself useful?**
- **Do you think the system gave you freedom as an individual learner?**
- **Do you think the system gave you more control of the learning task?**
- **Do you think that this system would suit many other learning tasks or subjects?**
- **Did the system become easier to use as you became more familiar with it?**

There is no attempt to provide statistical analysis because the sample size is too small. However, the claim to be encouraged by this initial feedback is genuine.

5.2 Feedback from Limited Web Trials:

Similar questions from the on line feedback for the two experimental versions of SPIKE received similar responses. Again the sample size was small (5 forms) and justifiable conclusions cannot be drawn from them. Even with this small sample, although the feedback was encouraging it was less consistent. One possible reason for this is that the first group (5.1) had a real need to access the material because they were learning the subject. The second group were accessing it to evaluate the approach rather than to learn anything.

5.3 Feedback from a Business Seminar

A small seminar was held for business on 14th February 2003. Out of 16 people that attended, 11 filled in questionnaires designed to find out what they thought of the ideas of KSM and SPIKE, 10 of these answered value related questions whilst all answered descriptive questions. The average response (1..10 concerning how strongly you support this statement) to how much the learner would be supported by the SPIKE environment was 69% (high level of agreement). The average response concerning the usefulness of using knowledge nodes to access material was even higher at 86%. However, the idea that it is acceptable to withhold some information from the learner as part of this environment was only 53%. Written comment concerning the value of KSM and SPIKE were very encouraging with most enthusiasm being expressed for the core concept of the KSM.

5.4 Small vs Large systems

There are several sorts of Knowledge Structure Map. Small maps containing less that 35 nodes are useful to address very specific issues. They have been used to explore certain knowledge topics such as negotiation. The current example of 'chairing meetings' was developed as a smaller map to facilitate discussion and analysis. More practical maps would be about the size of the earlier CD ROM system (about 120 nodes). Such maps provide the scope to explore a more comprehensive knowledge area. If only 15 minutes was reserved to study and consider each node or piece of knowledge, this would mean that a 120 node map would represent about 30 hours of study.

The small and larger maps described above are both manageable from a visualisation perspective. This means that such maps could be drawn out in a way that helps the learner to see the learning task and

how to make progress. If the number of nodes is tripled or quadrupled or even more nodes are used then the whole map becomes difficult to use from a visual perspective. This means that if a large subject area were to be represented in this way that visualisation would be difficult although other learning support features would persist. To recapture the other learning support features it would be necessary to use additional viewing strategies. These may include:

1) Displaying only parts of the map

2) Collapsing parts of the map into parent nodes

3) Sequencing certain branching options

Such strategies, if successful could mean that KSMs could be used to organise and provide access to very large knowledge areas, possible even learning resource data bases indexed by learning needs rather than by topic or alphabet.

5.5 Using KSMs to index learning material

The idea of using a KSM to index learning material in the way previously introduced is worth consideration. It could not replace an overriding topic index but once a learning goal was located it could transcend topic compartmentalisation. It would do this by identifying in the prerequisite direction, any required prerequisite knowledge regardless of its perceived topic speciality. For instance students studying electronics and those studying architecture may both want to know about resonance but may want to build on this knowledge in different ways. A KSM could also provide study options after the learning goal has been achieved. A student may want to know what could be studied in order to take most benefit from the things that had already been studied. So the learning material repository could offer study advice from a learning perspective.

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