The major theoretical assumption underpinning my research, and that of my colleagues, into proof is that human beings have the potential to develop a memory system as not yet widely recognized. This memory system is *explanative memory* – a memory for the form, shape and dramatic impact of proofs and explanations. Memory systems widely recognized as such include implicit and declarative memory. Subsystems of declarative memory include semantic memory (memory for facts) and episodic memory (memory for events). Subsystems of implicit memory include procedural memory for skills and habits, and a number of systems associated with non associative learning and priming. We propose explanative memory as a subsystem of declarative memory: explanative memory is a memory for the form and function of explanations.

Importantly, we postulate that without a developed ability to form and retrieve explanative memories, students can neither comprehend nor construct proofs.

**Some big questions**

Some major questions arise from looking at proof in this way.

1. Are there distinct brain areas or functioning that would consolidate the view of explanative memory as a distinct form of memory?
2. Can students learn to develop explanative memory? In particular, can teachers assist students to do this?
Questions we have answered

We feel we have forged a link between proof and the neuroscience of memory. This is still in the theoretical and speculative stage, but the data comes from experiences in real classrooms in real time lessons. Our first working this area was to delineate a role for a teacher in the formation of more declarative memories in mathematics classrooms (Davis, G., Hill, D. & Smith, N. (2000) A memory-based model for aspects of mathematics teaching. In T. Nakahara & M. Koyama (Eds.) Proceedings of the 24th conference of the International Group for the Psychology of Mathematics Education, vol 2, p.225-232. Hiroshima, Japan: Hiroshima University). This has proved to be a very useful perspective for examining teaching practices.

Experimental techniques and standards of evidence

Our basic experimental techniques fall into two groups. The big questions we discuss below indicate clearly that one collection of experimental techniques is associated with mapping brain function of people engaged in real time in proof activities. This is a sort of measurement and mapping technique. The other set of experimental techniques are similar in nature to existing memory experiments in psychology that involve students in recall of aspects of reasoning. Since, we hypothesize, explanatory memory is part of declarative memory, declarative artifacts such as writing and speech will form the data to be analyzed.

Experiments to answer the big questions

* Are there distinct brain areas or functioning that would consolidate the view of explanatory memory as a distinct form of memory? We have discussed this with Terrence Deacon, Professor of Biological Anthropology and Neuroscience at U. C. Berkeley, and author of “The Symbolic species.” His view, with which we concur, is that the human brain almost certainly did not evolve in response to doing things such as mathematical proof. Therefore, the fact that – some – people can produce and understand proofs, indicates that the human brain probably recruits other brain centers and functions in an advantageous way. To see how this might work, we have discussed with Deacon the idea that we take a simple yet puzzling fact for many people – that a polyomino made from unit squares always has an even perimeter – and carry out fMRI or, better, magneto encephalography, on highly mathematically trained, and relatively mathematically naïve, people to see what difference, if any, in brain functioning are evident as they think about an explanation for this fact. Deacon has invited us to visit his laboratory in Berkeley to discuss the feasibility of a series of experiments.
Can students learn to develop explanative memory? In particular, can teachers assist students to do this? We are following our guess that explanative memory as a distinct biological memory system is real. If this turns out to be the case, a big question is how to stimulate this memory system. This is not dissimilar to students learning to form and utilize mathematical facts in contexts different from which they learn them. In prior work with Lisa Warner and others, we have looked at this highly relational form of memory, almost certainly involving the hippocampus, and we have found there indeed are conditions under which this flexible thinking can be stimulated: the Pirie-Kieran model for learning provides a major analytical tool in dissecting how such flexible thinking develops. The techniques I would like to see tried here involve teachers working with students in settings in which explanations for puzzling facts are viewed as a dramatic mystery – much in the vein of a whodunit.

Connections with the work of others

The original motivation in beginning work on students’ ability to engage with construction of proofs came from Richard Skemp’s work on understanding. We – my colleagues and I – wanted to avoid the “u” word (“understanding”) because we felt no-one could satisfactorily describe what it was supposed to mean (a bit like “consciousness”). So we began to look at simple proof constructions – such as why a polyomino made from unit squares always has an even perimeter. We saw striking examples where a very few students could do this very well, and analysis of their actions and thoughts led us to – somewhat fancifully – talk about a “why-checker” utilized by these students. This language led us fairly quickly to work on memory systems and to the idea of a proof explanation as dramatic assemblage of known and relevant facts, built into a dramatic, and compelling story.