

‘Conjecture–First’ Problem Solving

Abstract

This paper is about rethinking the so-called steps to problem solving (decision making or system development). It will be argued that the steps have been misconstrued. The assumption that there is or should be impartial thought before jumping to a conjecture is questioned. This argument will be supported by revisiting the words and examples of Dewey, Polya and Mintzberg. The implications for being more accepting of how people actually think are explored.

Opening

The object under study in this paper is problem solving. The author is concerned that the conventional wisdom about how humans solve problems has been badly constructed. These concerns are not new, many writers including Mason and Mitroff (1981) and Mintzberg and Westley (2001) have reported a mismatch between what problem solvers actually do and the traditional ‘steps’ of good problem solving. The modern foundation of the ‘steps’ root metaphor appears to be from Dewey’s (1910) ‘How We Think’. These seem to have been misinterpreted by overlaying objectivism. The traditional steps are typified by Mintzberg and Westly (2001), and includes defining...the problem, diagnosing the causes, designing solutions, choosing and implementing the solution. At its core is the idea that the solution comes after the collection of information. However, I suspect this is not what Dewey intended, which is why he called human problem solving, reflective thinking.

This paper will try and re-present Dewey’s argument that the stepping stones to problem solving place tentative solutions or conjectures (to use his word) prior to a process of rational justification (reflection). The evidence that will be used to support this argument starts with Dewey’s own words and examples. It goes on to look at Polya’s problem solving advice (1945), Popper’s writings on conjecture (1963), Rittel’s wicked problems definition (1973), Crosswhite’s argumentation theory (1996), and Guindon’s (1990) empirical findings. It is believed that there is a thread through this work which the mainstream of the thinking literature has ignored. This is perhaps because the inductive ideas of science have dominated the psychological ideas of the operation of the human brain as struggling to give instant pattern recognition to sensory input.

I suspect those readers who pride themselves on their scientific, rational thinking would be very uncomfortable with the idea that problem solutions arrive prior to any reasoned thinking process, including the collection of relevant information. Those who follow Checkland’s (2000) Riddel’s (1973) and Mason and Mitroff’s (1981) ideas that problem appreciation *is* problem solving will also feel uncomfortable as appreciation is traditionally thought to occur before solutions can be considered. This uncomfortable feeling would seem to come from a deeply held assumption reflected in Sherlock Holmes’ advice to Watson not to guess ‘who-done-it’ until all the evidence has been collected. However, I am suggesting these traditional scientific stages to rational

thinking are a non evolutionary interpretation of deep thinking in humans. Dewey by contrast presents the evolutionary approach.

John Dewey (1859–1952)

Dewey, described by some as the most influential philosopher on thinking and education in the 20th Century, spent the second half of his life in the department of philosophy at Columbia University. Like Schon, he is thought of as a writer on educational philosophy yet both of their works have been seminal to the management literature. Newell and Simon (1972) cite Dewey in their own oft cited book ‘Human Problem Solving,’ as does Churchman (1971) in his [oft cited] book, ‘The Design of Inquiry Systems’. Simon won a Nobel prize and Churchman was short-listed. In more modern times Mintzberg (2001), a seminal figure in the management research literature, directly attributes the rational steps of decision making to Dewey (1910). Dewey spells out the steps (or as he says, constituents) of reflective thinking, in his small book, ‘How We Think’.

Dewey’s book starts by defining thinking, which he wants to distinguish from ‘daydreaming’. He specifically means focused, purposeful, rational and intelligent thinking. He uses the label ‘reflective thinking’ in a way we might talk of ‘critical’, ‘careful’, ‘considered’, or ‘deep’ thinking today, but importantly he inserts the word ‘reflective’ apparently in order to emphasise critically reflecting on a prior belief, ‘first thought’, conjecture or some other ‘supposed form of knowledge’.

Active, persistent, and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and further conclusions to which it tends, constitutes reflective thought...

...it is a conscious and voluntary effort to establish belief upon a firm basis of reasons [1910, p. 3].

In the second part of the book (which starts at chapter 6) Dewey explains how this “established belief upon a firm basis of reasons” might be analysed (where analysed is distinguished from synthesised). The analysis or “picking apart” (zooming in) provides the ‘steps’ (constituents, parts) and is spelt out under the chapter heading, “The Analysis of a Complete Act of Thought”. He starts by presenting three everyday examples of thinking. The first of these is:

1. The other day when I was downtown on 16th Street a clock caught my eye. I saw that the hands pointed to 12.20. This suggested that I had an engagement at 124th Street, at one o’clock. I reasoned that as it had taken me an hour to come down on a surface car, I should probably be twenty minutes late if I returned the same way. I might save 20 minutes by a subway express. But was there a station near? If not, I might lose more than 20 minutes looking for one. Then, I thought of the elevated train?, and I saw there was such a line within two blocks. But where was the station? If it were several blocks above or below the street I was on, I should lose time instead of gaining it. My mind went back to the subway express as quicker than the elevated; furthermore, I remembered that it went nearer than the elevated to the part of 124th Street I wished to reach, so that time would be saved at the

end of the journey. I concluded in favour of the subway, and reached my destination by one o'clock. (1910, p. 69)

After presenting two other examples Dewey sees some emergent properties in thinking:

Upon examination, each instance reveals, more or less clearly, five logically distinct steps: (i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solution; (iv) development by reasoning of the bearings of the solution; (v) further observation and experiment leading to its acceptance or rejection; that is the conclusion of belief or disbelief [1910, p. 72].

This appears to be the origins of the idea of what has become the five stages of decision making. Dewey quickly explains that steps (i) and (ii) frequently fuse. So mapping the steps on the example that he provides, my interpretation is as follows:

Problem Definition/Appreciation:

The other day when I was downtown on 16th Street a clock caught my eye. I saw that the hands pointed to 12.20. This suggested that I had an engagement at 124th Street, at one o'clock.? [thus he could be late for the appointment]

Possible Solution 1:

[He could take a surface car]

His reflection

I reasoned that as it had taken me an hour to come down on a surface car, I should probably be twenty minutes late if I returned the same way.

Possible Solution 2:

I might save 20 minutes by a subway express.

His reflection

But was there a station near? If not, I might lose more than 20 minutes looking for one

Possible Solution 3:

Then, I thought of the elevated ?,

His reflection

and I saw there was such a line within two blocks. But where was the station? If it were several blocks above or below the street I was on, I should lose time instead of gaining it.

Possible Solution 4:

My mind went back to the subway express as quicker than the elevated;

His reflection

I remembered that it went nearer than the elevated to the part of 124th Street I wished to reach, so that time would be saved at the end of the journey.

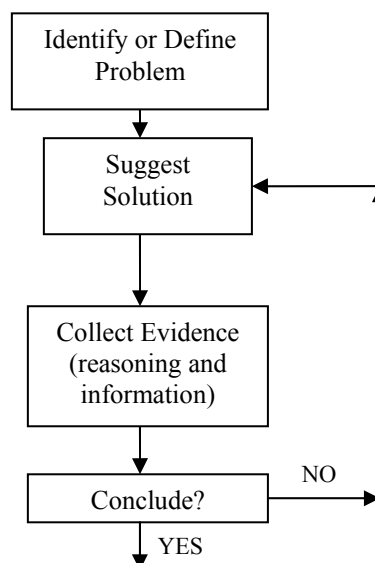
Conclusion

I concluded in favour of the subway, and reached my destination by one o'clock.

As a flowchart, his steps of thinking might look like figure 1. The feature I am trying to highlight is that a quickly guessed or 'first' solution seems to come *before* the collection of supporting evidence (as reasoning or as empirics). This is why Dewey calls it 'reflective thinking', that is, thinking back on a possible solution. Dewey provides synonyms for 'possible solution', 'first thought' or 'quick idea.' He suggests, 'conclusion', 'supposition', 'conjecture', 'guess', and 'hypothesis'.

This idea of placing the solution prior to the thinking will only be a novel suggestion to those unfamiliar with the ideas behind argumentative inquiry, or of the pattern recognition literature from psychology. Of course, the example provided are very simple, as are the other two examples that Dewey discusses. Both of which follow the same pattern. Seeing them as simple examples of thinking might however mistakenly open up the possibility of distinguishing reflective thinking as all right for quick everyday decisions, but not for important scientific thinking or project management. This would allow a return to the line of argument that 'jumped to conclusions' need to be avoided until after some careful consideration of the facts. I would suggest any split between everyday thinking and 'big project' thinking is an error, as the big project thinking only includes what is happening in the heads of the individuals involved in a project.

Figure 1: Dewey's Steps to Thinking



Empirical Support

Guindon (1990) provides empirical support for Dewey's examples. He compiled a two hour protocol analysis of three professional designers who are designing lift (elevator) control software. He struggles to apply Simon's ideas of ill-structured problems to describe the type of trial and error heuristic processes the designers went through to complete an effective design. These designers were well qualified, and very experienced. He concludes:

This study shows that the early stages of the design process are best characterised as opportunistic, (1990, p. 336)

He found that designers frequently guessed at solutions, and then thought about whether these would work when compared to the requirements. The 'guesses' were accepted, modified or rejected after further thought or testing. There was not a linear process of appreciating the requirements, collecting facts and selection of alternative solutions and then selecting a solution. Although Guindon does not mention Dewey, his description of how his designers solve their problem has similarities to the three examples provided by Dewey. Guindon, however, is concerned that his designers are not following Simon's interpretation of the traditional steps, suggesting this may be because humans only have bounded rationality and are imperfect at reasoning. This assumes Simon's problem solving algorithms are an idealised form of human problem solving that somewhat inadequate humans should aspire to. Dewey's interest is in how humans think.

Mintzberg (2001) has also noted that some problem solving seems to jump to the solution before any reasoning or evidence has been collected. He calls this the 'seeing first' approach (having insights) and contrasts it with the traditional step approach which he calls the 'thinking first' approach. Part of Mintzberg's critique of the 'thinking first' approach includes the experience that people often seem to have solutions in search of problems; hammers looking for nails. This seems to be a bit like Chamber's theory laden observation. Mintzberg cites March as characterising problem solving as:

...collections of choices looking for problems, issues and feelings looking for decision situations in which they may be aired, solutions looking for issues to which they might be an answer and decision makers looking for work. (2001, p. 90)

Mintzberg's 'seeing first' approach uses the example of a family seeing a black stool and declaring that this was the solution to the problem of the colour scheme for a new apartment. The apartment is then totally redesigned, successfully, around this stool. The thinking approach would have been to set the colour scheme (plan) and then find furniture and coverings to suit (actions) the plan.

Mintzberg's third option of 'doing first' thinking aligns with the action learning or practitioner ideas of Argyris and Schon which suggests that when a problem is identified just guess some action, do it and then think about what happened. Again, the thinking comes after the guessed solution. The doing is expected to provide some

experiences to think about. This might be seen as similar to the 'seeing approach' where the action is to 'see' rather than to act.

Therefore

Philosophers, researchers and experienced management theorists seem to have noticed that humans, when faced with a problem, jump to a tentative solution and then can choose to act to rationalise that conjecture using more critical thinking such as observation, reasoning and experimentation. If the solution is found wanting then it is rejected and another guess evaluated. This is different to the traditional view of rational thinking for solving problems, which required evidence to be collected first, some process of selecting from alternatives, and then a solution is selected. The essential difference is that in the reflective, opportunistic, seeing-first approach, starts with a conjecture.

Is there any sort of theory to suggest that the conjecture first approach is rational? Suggested below is a three stranded, but not mutually exclusive, set of justifications. One is an evolutionary perspective (stigmergy), one from a theory of knowledge and another from a child psychology perspective.

Conjecture First

Rapid and instinctive response to patterns recognised as threatening does appear to be justifiable in evolutionary terms. It would give survival advantages to those who had these skills. Examples include rapid hand closure on electrocution and rapid eye lid closure on perceiving the approach of explosive heat. These can be seen as a very instinctive form of problem solving. The rapid instinctive action would seem to involve the brain recognising and responding to what it sees as a danger. However, some readers may want to distinguish this sort of instinctive reaction from 'rational thinking'. Yet, these instant pattern recognition mental responses at least open the door to an approach to thinking that aligns with the idea that the brain very quickly jumps to conjectures, for it is a rapid pattern recognition organ. In the psychology literature this is often referred to as 'automatic thinking' [ref]. As Dewey seemed to be suggesting above, reflecting carefully, rationally, scientifically, methodically, and systematically, on instinctive responses is perhaps one way of understanding 'high level' thinking. It is to be contrasted with the idea that high level thinking starts with an empty, objective mind.

The 'automatic thinking' line of argument from psychology is that the human brain develops schema or mental models to enable us to interpret what we see. This is similar to Kant's a priori, Churchman's perspectival thinking, boundary shifting in systems thinking (Ackoff, 2000), Chalmer's theory laden observation and the ethics literature on framing (Werhane, 2002). At the cognitive level 'vision' can be explained as the brain very rapidly putting a pattern on to the stream of input sensed by the eye. This is perhaps appreciated by recounting the experiences of adults who undergo eye surgery to successfully correct birth defects causing blindness. In some cases the blindness is caused by a physical fault in the eye that can be corrected by surgery. After the operation, while technically their eye 'works', they are unable to decipher the confusing pattern of colours and lights entering their eye. This is apparently not due to some further fault with the optical nerves, rather

their brain has no schemas to interpret the shapes and patterns of light entering their eye. We need schemas to work with the sensory inputs to enable us to 'see'.

This may be analogous to how we think. We mix experience as recognised patterns with new sensory inputs. This reinforces the suggestion that when we think we automatically perceive of the problem from historic schemas or perspective (frames, theories, value, system boundaries) which are likely to be the result of genetic, childhood and broader social influences. This schema of perspective provides an explanation of what is thought about; it gives pattern. Creative thinking can then be defined as suggesting a new pattern, a new perspective on an old problem, one that the others involved in the problem had not considered.

Stigmergy is a term used in the self-organisation biology literature (Comazine et al., 2001) for this automatic response to recognised patterns leading to actioned responses. The experiments usually referred to are those of ants in laboratory Petri dishes. Individual ants have been observed to move sand about in a meaningless random manner until they spot a recognisable shape like a pupa cavity, after which their actions 'automatically' become one of constructively building extensions to this cavity. The shape triggers a responsive action. We can see a similar response in humans who see a person, word, structure, noise or some other pattern and respond intuitively. This may be a genetic response or a learnt one. An experienced problem solver can therefore be expected to respond rapidly to recognisable situations, jumping to very tentative conjectures.

The conjecture first approach can also be aligned with writings in the theory of knowledge philosophy. Many philosophers comment that questions are at the beginning of human thought. Crosswhite (1996) in his support for argumentative reasoning, argues however that we should really start with the tentative conjectures not the later verbalised question. Children, as well as dumb and deaf people and species without language, all of whom do not have the linguistic device of questioning, or without knowing what a question is, can solve problems. They can be expected to become confused as they try and impose a pattern on sensory input. They can also be expected somehow to make sense of these images or noises if only to classify them as 'problematic' by thinking up conjectures (solutions, ideas) that do or do not 'fit'. However, unless these people without questions have rational reasoning skills they might not justify their conjecture in an explicit manner which could aid community learning. Crosswhite, as philosopher, seems to agree that the brain jumps to conjectures based on genetics or experience almost instantly upon our receipt of new sensory input; it gives pattern and meaning to these inputs. If the patterns work then there is no problem; conversely if the guessed at patterns do not seem to fit the sensory input then a problem is declared. Inductive science suggests we should somehow suspend this instant pattern recognition, and rather collect evidence in a state of suspended judgement. Crosswhite feels this is not really possible and repressing this first impression will distort what is seen as relevant evidence. Rather he suggests we acknowledge explicitly what our brains have conjectured and set about confirming or disconfirming it in a methodical manner.

Removing the evolutionary perspective, the theory of knowledge literature also suggests this conjecture-first approach in two related ways. One way is Popper's (1963)

ideas of presenting conjectures for falsification. The other is inherent in argumentative inquiry. Popper's conjectures are meant to be more thought out than instinctive responses, but the basic layout of having an upfront explicit conjecture that needs to be proved to a sceptical audience is the analogous notion. It was intended to be contrasted with the discovery approach of seeking evidence prior to finding some solution. The difference seems to come down mainly to whether you believe that the first thoughts conjectures can be completely set aside prior to evidence collection and whether *non* theory driven observation can be undertaken.

The use of competitive argument (reasoned debate not quarrelling) as a means of argumentative inquiry, rather than primarily persuasion, now has a number of advocates (Perelman, 1969; van Eemeren 1987, Walton, 1998, List and Metcalfe, 2003). As with Popper, the idea is that an advocate declares a knowledge claim to start a competitive inquiry process with a sceptical knowledgeable audience. From this process it is intended that an improved and fully justified knowledge claim emerges. Churchman extends this to seeking participants perspectives of complex social problems. These perspectives need to be justified to the sceptical audience.

Polya

Another strand of thinking that appears to support the 'conjecture-first' approach to thinking may be drawn from the words of that classic problem solving text by Polya (1945); 'How To Solve It'. This booklet is aimed at mathematicians. It provides a suggested methodology to tackle the creative process of solving mathematical and geometric problems. His 'steps' are:

"First. You have to understand the problem"

Second. Find the connection between the data and the unknown. You may be obliged to consider auxiliary problems if an immediate connection cannot be found. You should obtain eventually a plan of the solution.

Third. Carry out your plan

Fourth. Examine the solution obtained" [1945, p. xvi]

Polya then provides further elaboration of what he meant under the second step in terms of needing to seek analogous problems that have been solved. He suggests using existing solutions to old problems. This is further understood by his elaboration of the third step which he states as testing to see if the old analogous solution or at least similar concepts work for the new problem. Polya, who is a well respected author on problem solving, is therefore not suggesting that solutions come after reasoning about alternatives. Rather, he suggests that you search for a conjecture solution (from an analogous problem) and then think about its usefulness for the current problem. This again seems very much like Dewey's advice and the advice of argumentative inquiry: conjecture something that might work, and then think about the feasibility of this solution carefully.

Wicked Problems

Polya's advice was aimed at mathematical problems while Dewey's was aimed at everyday problems and social research. This raises the issue of whether there is a need to distinguish simple from complex problems in terms of how solutions are sought. Rittel and Webber (1973) seems to have influenced Churchman and his students, Mason and Mitroff (1981) into thinking that 'wicked' problems need a significantly different approach than simple problems. Simple problems are typically identified as mathematical or physical sciences problems and 'wicked' problems were complex social problems, such as poverty. Rittel and Webber (1973) define a wicked problem as one where:

1. *There is no definitive formulation of a wicked problem.*
2. *Wicked problems have no stopping rule.*
3. *Solutions to wicked problems are not true-or-false, but good-or-bad.*
4. *There is no immediate and no ultimate test of a solution to a wicked problem.*
5. *Every solution to a wicked problem is a 'one-shot operation'; since there is no opportunity to learn by trial and error, every attempt counts significantly.*
6. *Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.*
7. *Every wicked problem is essentially unique.*
8. *Every wicked problem can be considered to be a symptom of another problem.*
9. *The existence of discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.*
10. *The planner has no right to be wrong. [1973, p. 161-166].*

Dewey's problem of how to get to his next appointment matches at least the first nine¹ of these descriptions of a wicked problem. It does not match the traditional problem solving advice to first identify all the possible solutions and then to fully evaluate each. Leaving aside the definition issue for a moment, items 2 and 6 (numerous problem definitions and solutions) do however seem to match the conjecture-first approach as they suggest that the problem solver is free to think up as many conjectures as the situation permits. Given the likely influence of Dewey on Rittel this may not be surprising. Items 3 and 4 (no best solutions) were covered because there was no definitive proof that the evidence of the goodness of any conjecture solution was not absolutely 'true'. Rittel writes of problem 'resolving' in place of problem solving in order to suggest both that the solution is socially constructed and likely to be open to re-solving later.

Items 5 and 7 (solutions are not generalisable) are covered in Dewey's appointment example because he has to get to this particular appointment, at this particular time. All the conjectures and supporting evidence are only relevant to this one off situation. Repetitive experiments for generalised results are not possible.

Item 8 reminds me of Ackoff's (2000) call for problems to be dissolved not solved. Typically, this involves seeing the problem systems as a sub-system of some wider

¹ Rittel and Webber's point number ten appears to introduce a moral imperative into solving wicked problem so as to avoid unethical experimental actions which affect people's lives.

system and looking to redefine the sub-system. For example, his dissolving of an industrial dispute between bus conductors and drivers involved moving the problem perspective to the 'wider' systems view of the bus company's operations. He wanted to consider the relative number of buses to bus-stops. Dewey's appointment example problem could also be shifted to a wider city transport system problem, a multi-campus lecturer's problem as well as an appointments scheduling problem. Dewey did not want to solve these wider problems, but nevertheless if the wider problem was solved, his problem would disappear. A conjecture solution can make use of this shifting perspective on the level of the sub or supra-system's being considered to explore solutions.

This issue of selecting an appropriate perspective may be another way to define how complicated a problem is, or is wanted to be. Dewey's appointment problem is not seen as complicated because it appears to be solvable at the level within his immediate and sole control. If it was necessary to redesign the city transport then this would be understood to be a much more complicated problem involving stakeholders over time. Put the other way around, a problem can be made simpler by zooming down to one of its sub-components; a very science solution. If Dewey had decided to do this and reduced the problem to how to get there by (say) subway then the issues would have become, where is the station, which platform do I need and so on....

So in summary, in situations of socially constructed problems and solutions, with imperfect knowledge, under time constraints, the approach of finding solutions by exploring conjectures seems to be appropriate. These conjectures are generated from experience in an opportunistic (brainstorming) manner. There is no possibility of exploring all the possible solutions and fully evaluating them. It may appear to be a sub-optimal approach, but the situation is too complex, and too socially constructed for concepts like a complete set of solutions to be useful. The problem solving task becomes one of finding a solution that works well enough to stop those involved being concerned.

Appreciating Is Solving

As discussed earlier, those trained in the traditional steps of decision making tend to assume that appreciating a problem comes before solving a problem. In the conjecture-first perspective the two are almost synonymous. Put crudely, defining or appreciating a problem *is* solving the problem, or at least generating conjecture solutions that will need to be rigorously evaluated (Checkland, 2000; Rittel 1973; Mason and Mitroff, 1981). Processes designed to help stakeholders understand a problem, such as rich picturing, project briefs, electronic brainstorming meetings and storytelling are at the same time constructing solutions. This is so at two levels. First, if the brain is a pattern recognition organ then as the problem is explained, understood or appreciated, the brain will be jumping to conjecture solutions, automatically. Second, whoever or however the problem is explained will bring with it a certain perspective. Better problem appreciation methods will make this as explicit as possible. For example, Dewey presented his appointment example from the perspective of a choice between three transport alternatives. He did not present it from the perspective of a city transport design problem. His method of presentation influenced the range of conjecture solutions (patterns) that his brain supplies.

How then would an advocate of conjecture-first problem solving facilitate a meeting to discuss a problem? Briefly the approach would need to be one of describing the problem from a range of perspectives. This may be something like Morgan's metaphors (1996), Linstone's Technical, Organisational and Personal perspectives (1999), Liebl's stakeholder and issue analysis (2002), Checkland's Rich Picturing or for the more radical, a word generation software like "Randomword".

[<http://www.infinn.com/randomword.html>]. Out of this exercise the first thought conjectures of participants need to be made explicit, perhaps in a confidential manner. List and Metcalfe (2003) suggest this can be done in the form of a proposition (argument, claim). For example, "That X is Y and not Z". These can then be thought through in more detail. Popper's falsification ideas may also be useful. Having articulated the conjecture, then falsifying (disconfirming) evidence should be sought.

Summation

This paper has argued that the brain is a pattern recognition organ, so "jumping to conclusions" happens. Rather than chastise the practice as a human frailty, this paper argues that the practice be made explicit and formalised into a process for careful rational even scientific thought. The traditional 'steps' to decision making are more akin to espoused theory than reality. The empirical evidence is that it is not how problem solving actually occurs. Further, the foundational philosophers who are usually attributed to recommending the step approach are being mis-interpreted. The steps were not advocated for mathematical problems in the way modern writers repeat, but more so for wicked problems when solutions are a matter of opinion.

Naming is a problem. Guindon (1990) called the process of rapidly guessing solutions and then carefully thinking about how viable the idea is, opportunistic thinking. Dewey called it reflective thinking. It seems analogous to Popper's research design of communities arguing over an up front conjecture. The term 'jumping to conclusion' has negative connotations, as it should if these conclusions (conjectures) are not thoughtfully reflected upon prior to being acted upon. Argumentation theory provides the mechanism for thinking about a 'first thoughts'.

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