**Chapter 5 – Algorithms and Transparent Critical Thinking**

**Introduction**

This chapter explores the possibility that critical thinking can be made more transparent by using algorithms in the processing of the data. As seen previously, the focus is on the ideas presented by the authors in scientific documents. The process involves the following tasks:

1. Organize the terms used in the ideas – most frequent to least frequent.
2. Select high frequency terms (***direct)*** that also are specific to the topic.
3. Identify terms (potentially ***indirect***) linked to each of the direct terms.
4. Build a matrix of direct terms and their associated terms.
5. Identify indirect terms that occurred with higher consistency across the direct set.
6. Identify terms (***associated***) linked to each of the indirect terms.
7. Build a matrix of indirect terms and their associated terms.
8. Determine the frequency and consistency of use of these associated terms.
9. Build an idea map showing the direct, indirect, and highest frequency associated terms.
10. Use that map to build different research designs using the research design template.
11. Determine measures to use in describing and evaluating each design.
12. Array those designs from ‘best’ to ‘less’ using those measures.
13. Translate the ‘best’ design into a protocol.

**Tasks**

**Organize Terms in Ideas:** The vocabulary used by authors can be organized with respect to the frequency of each used in ideas. Table 1 shows an excerpt of this vocabulary array.

**Table 1. Frequency of Terms in Ideas.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Total** | **Term** | **Total** | **Term** | **Total** | **Term** | **Total** |
| Total Ideas | 3029428 |  |  |  |  |  |  |
| dog | 237235 | animal | 31831 | lesion | 17971 | chemical | 13285 |
| cell | 57704 | blood | 27170 | induce | 16570 | health | 13061 |
| disease | 56596 | tumor | 23050 | breed | 15669 | abnormal | 13013 |
| canine | 54367 | protein | 22396 | antigen | 15620 | histologic | 12592 |
| clinic | 52023 | amine | 20973 | radiograph | 13942 | **Etc**. |  |
| infect | 47754 | virus | 20153 | chronic | 13637 |  |  |
| normal | 36342 | diagnosis | 18186 | antibodies | 13340 |  |  |
| infection | 34211 | response | 18112 | fusion | 13334 |  |  |

The next task involves separating these high frequency terms into two sets – those that provide specific meaning relative to the topic (dog disease) and those that are more general in meaning.

Table 2 shows a subset of those specific meaning higher frequency terms. In this example, dog would be described by core terms – infect, virus, tumor, and response. While other terms would expand on this basic description, these offer a first step.

**Table 2. High Frequency Specific Terms.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | | **Infect** | **Tumor** | **Virus** | **Response** | **Sum** |
| Grand sum | 84157 | | 22270 | 28657 | 17721 | 152805 |
| dog | 8427 | | 2042 | 1696 | 1593 | 13758 |
| infect | 7105 | | 24 | 1160 | 279 | 8568 |
| response | 474 | | 183 | 112 | 0 | 769 |
| tumor | 51 | | 24 | 36 | 181 | 292 |
| virus | 1543 | | 29 | 1513 | 84 | 3169 |

**Table 3. High Frequency General Terms.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Dog** | **Infect** | **Tumor** | **Virus** | **Response** | **Sum** |
| disease | 5510 | 1782 | 195 | 493 | 261 | 8241 |
| clinic | 5708 | 1376 | 307 | 192 | 379 | 7962 |
| canine | 2554 | 1608 | 803 | 2169 | 250 | 7384 |
| cell | 2966 | 920 | 1481 | 533 | 467 | 6367 |
| animal | 3002 | 1253 | 177 | 297 | 177 | 4906 |
| normal | 3650 | 247 | 255 | 38 | 232 | 4422 |
| blood | 2514 | 553 | 115 | 81 | 154 | 3417 |
| breed | 2621 | 168 | 60 | 39 | 49 | 2937 |
| amine | 2054 | 402 | 114 | 130 | 152 | 2852 |
| health | 2155 | 325 | 39 | 80 | 55 | 2654 |
| antigen | 1043 | 643 | 97 | 396 | 200 | 2379 |
| protein | 1365 | 342 | 166 | 349 | 134 | 2356 |

Table 3 shows an excerpt from the higher frequency and more general terms linked with dog. These terms may play a role in describing dog disease but in a more indirect way. As such, their links with the direct terms is the next task to determine.

Identification of potentially indirect terms involves primarily consistency of use of the term across different direct terms and only secondarily, frequency of occurrence. Again, possible terms are separated by specificity of meaning. Table 4 shows the consistent terms that also have more specific meaning.

**Table 4. Consistent, Specific Terms That May Serve as Indirect in Describing Dog Disease.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Dog** | **Infect** | **Tumor** | **Virus** | **Response** | **Sum** |
| coronary | 774 | 2 | 0 | 1 | 78 | 855 |
| larvae | 168 | 261 | 0 | 6 | 10 | 445 |
| flea | 355 | 73 | 0 | 1 | 13 | 442 |
| allergen | 318 | 13 | 0 | 2 | 57 | 390 |
| diabetic | 345 | 12 | 5 | 0 | 13 | 375 |
| remission | 278 | 8 | 39 | 0 | 42 | 367 |
| metastasis | 203 | 7 | 141 | 0 | 7 | 358 |

**Table 5. Consistent, General Terms.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Dog** | **Infect** | **Tumor** | **Virus** | **Response** | **Sum** |
| caninum | 312 | 371 | 0 | 9 | 6 | 698 |
| occlusion | 558 | 15 | 2 | 0 | 55 | 630 |
| atopic | 521 | 27 | 0 | 4 | 53 | 605 |
| egg | 279 | 180 | 0 | 11 | 5 | 475 |
| arterial | 379 | 23 | 9 | 0 | 39 | 450 |
| gibsoni | 177 | 257 | 0 | 4 | 10 | 448 |
| lameness | 405 | 20 | 5 | 0 | 9 | 439 |
| dosage | 319 | 42 | 20 | 0 | 24 | 405 |
| adrenal | 291 | 9 | 64 | 0 | 38 | 402 |

Table 5 shows an excerpt of the consistent but general meaning terms. They would be passed over in selecting indirect terms but may be used in further describing the idea structure involving direct, indirect, and associated terms.

**Table 6. Direct and Indirect Terms in a Matrix.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Corornary** | **Larvae** | **Flea** | **Allergen** | **Diabetic** | **Remission** | **Metastases** | **Sum** | **Consist** |
| dog | 775 | 226 | 355 | 327 | 620 | 278 | 382 | 2963 | 7 |
| infect | 1 | 227 | 46 | 6 | 11 | 4 | 4 | 299 | 7 |
| response | 78 | 14 | 13 | 60 | 28 | 42 | 10 | 245 | 7 |
| tumor | 0 | 0 | 0 | 0 | 14 | 39 | 241 | 294 | 3 |

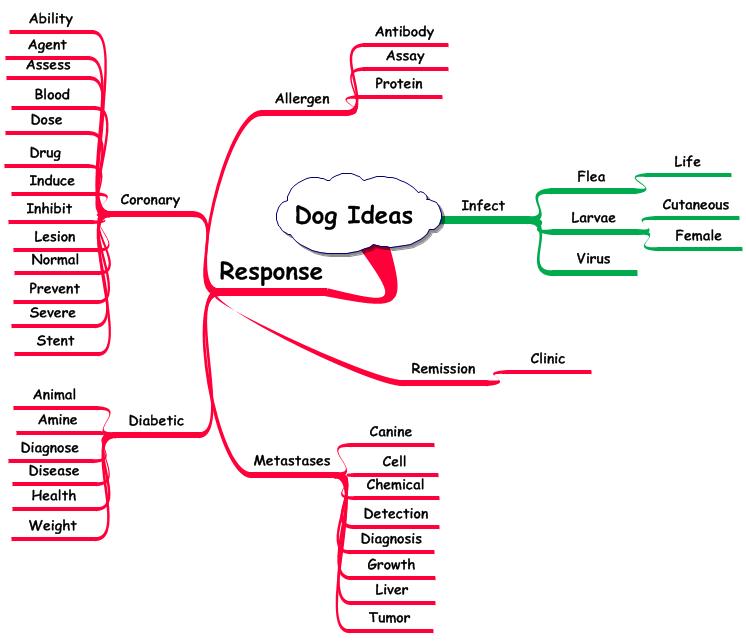
Table 6 shows the links between the direct terms (row headings) and the indirect ones (column headings). The consistency of use also is shown in the final column.

**Table 7. Associated Terms Linked with Indirect Terms.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Term** | **Corornary** | **Larvae** | **Flea** | **Allergen** | **Diabetic** | **Remission** | **Metastases** |
| Grand Sum | 9872 | 2794 | 2094 | 3330 | 4306 | 1674 | 3655 |
| blood | **365** | 21 | 20 | 11 | 73 | 6 | 5 |
| disease | 78 | 26 | 31 | 77 | **101** | 45 | 52 |
| clinic | 22 | 17 | 29 | 67 | 83 | **85** | 50 |
| animal | 68 | 25 | 52 | 49 | **84** | 9 | 23 |
| induce | **198** | 6 | 10 | 25 | 29 | 27 | 6 |
| amine | **105** | 30 | 21 | 41 | 67 | 3 | 18 |
| canine | 66 | 20 | 15 | 43 | 62 | 11 | **68** |
| cell | 30 | 8 | 12 | 24 | **51** | 29 | 94 |
| normal | **102** | 5 | 7 | 15 | 69 | 17 | 19 |
| assess | **57** | 6 | 19 | 33 | 11 | 10 | 8 |
| dose | **61** | 15 | 11 | 6 | 13 | 21 | 7 |
| diagnosis | 1 | 20 | 7 | 29 | 23 | 6 | **46** |
| lesion | **41** | 9 | 6 | 4 | 15 | 12 | 29 |
| protein | 15 | 5 | 5 | **43** | 21 | 4 | 14 |
| liver | 12 | 23 | 2 | 3 | 7 | 3 | **55** |
| health | 4 | 9 | 12 | 13 | **48** | 7 | 3 |
| diagnose | 1 | 7 | 5 | 10 | **38** | 4 | 29 |
| prevent | **43** | 14 | 18 | 8 | 7 | 3 | 1 |
| inhibit | **55** | 3 | 2 | 15 | 6 | 1 | 10 |
| severe | **37** | 8 | 3 | 6 | 16 | 6 | 1 |
| drug | **35** | 6 | 4 | 7 | 4 | 16 | 4 |
| assay | 3 | 15 | 10 | **31** | 9 | 1 | 3 |
| cutaneous | 8 | **23** | 1 | 16 | 4 | 3 | 16 |
| female | 1 | **27** | 14 | 1 | 11 | 4 | 11 |
| ability | **22** | 12 | 8 | 4 | 11 | 7 | 4 |
| agent | **29** | 6 | 9 | 6 | 6 | 9 | 3 |
| stent | **25** | 7 | 2 | 9 | 13 | 1 | 7 |
| growth | 6 | 6 | 2 | 2 | 2 | 3 | **42** |
| life | 5 | 11 | **13** | 10 | 12 | 4 | 7 |
| antibody | 4 | 15 | 6 | **21** | 6 | 5 | 2 |
| chemical | 5 | 2 | 1 | 3 | 16 | 2 | **28** |
| detection | 7 | 9 | 3 | 10 | 3 | 1 | **21** |
| weight | 3 | **14** | 3 | 9 | **14** | 4 | 7 |
| analysis | **11** | 3 | 6 | 9 | 6 | 7 | 10 |
| breed | 2 | 6 | 4 | 3 | **24** | 1 | 9 |
| intestinal | 1 | **22** | 6 | 2 | 5 | 2 | 3 |
| proteins | 4 | 3 | 3 | **24** | 4 | 1 | 1 |
| absence | 11 | 1 | 2 | 3 | **12** | 1 | 7 |
| acid | **16** | 2 | 1 | 1 | 13 | 3 | 1 |
| pathogen | 7 | 2 | **11** | 8 | 6 | 1 | 2 |
| articular | 1 | 9 | 5 | **10** | 5 | 1 | 4 |
| parent | 5 | **8** | 2 | 6 | 5 | 3 | 6 |
| respond | 7 | 4 | 4 | 7 | 2 | **8** | 1 |
| hospital | 2 | 1 | 2 | **12** | 6 | 1 | 2 |
| inflammation | 4 | 5 | 1 | **9** | 1 | 1 | 3 |
| information | 6 | 1 | 2 | 2 | 4 | 2 | **7** |
| blind | 1 | 1 | 4 | **8** | 4 | 1 | 1 |
| mortality | **4** | 3 | 1 | **4** | **4** | 1 | 3 |
| neutrophil | **6** | 1 | 1 | 1 | **6** | 2 | 1 |

Table 7 shows the other terms associated with the indirect ones. The selection criterion was a consistency of 7. The highest frequency idea for each indirect-associated term combination is highlighted in red. As the total occurrence of the idea reduces, the frequent idea becomes less obvious with duplicates and triplets showing the same low frequencies.

**Figure 1. Higher Frequency Ideas Linked with Dog.**

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The idea map in Figure 1 shows the higher frequency terms all linked with the central term – dog – as well as to direct and indirect terms forming the idea structure. In this map, the direct idea – dog & response – forms a basis for expansion of indirect and associated terms.

**Response Related Ideas**

The response ideas were further explored by classifying them into dimensions representing components of the relationship between – dog & response. The dimensions were:

1. Personal Factors – those variables describing the study participants.
2. Subject Factors – those variables describing the topic. Sub-dimensions included:
   1. Chemicals
   2. Pathogens
   3. Cancers
   4. Tissues
   5. Immune
3. Treatment Factors – those variables describing the types of interventions.
4. Outcome Factors – those variables describing the interactions between interventions and subject factors.
5. Method Factors – those variables describing procedures used.

Tables 8A – 8J show excerpts from the different dimensions. The higher frequency terms are shown.

**Table 8A – Higher Frequency Terms Linked**

**with the Central Term – Response: Personal Factors.**

|  |  |
| --- | --- |
| **Term** | **Personal** |
| dog | 1593 |
| canine | 250 |
| animal | 177 |
| breed | 49 |
| weight | 35 |
| infant | 32 |
| beagle | 26 |
| parent | 24 |
| puppies | 20 |

**Table 8B – Higher Frequency Terms Linked**

**with the Central Term – Response: Subject Factors**

|  |  |
| --- | --- |
| **Term** | **Subject** |
| disease | 261 |
| humoral | 114 |
| chronic | 101 |
| occlusion | 55 |
| agent | 53 |
| proliferative | 44 |
| distemper | 39 |
| stress | 38 |

**Table 8C – Higher Frequency Terms Linked**

**with the Central Term – Response: Cancers**

|  |  |
| --- | --- |
| **Term** | **Cancer** |
| lymphoma | 34 |
| cancer | 33 |
| sarcoma | 16 |
| melanoma | 16 |
| necrosis | 12 |
| neoplasm | 12 |
| metastatic | 12 |

**Table 8D – Higher Frequency Terms Linked**

**with the Central Term – Response: Immune**

|  |  |
| --- | --- |
| **Term** | **Immune** |
| infect | 279 |
| antibody | 214 |
| antigen | 200 |
| inflammatory | 167 |
| allergen | 57 |
| mitogen | 57 |
| antibodies | 54 |
| immunologic | 53 |

**Table 8E – Higher Frequency Terms Linked**

**with the Central Term – Response: Chemical**

|  |  |
| --- | --- |
| **Term** | **Chemical** |
| hormone | 74 |
| choline | 51 |
| acid | 50 |
| cytokine | 45 |
| enzyme | 42 |
| proteins | 41 |
| adenosine | 41 |
| histamine | 40 |
| cortisol | 38 |

**Table 8F – Higher Frequency Terms Linked**

**with the Central Term – Response: Pathogen**

|  |  |
| --- | --- |
| **Term** | **Pathogen** |
| virus | 84 |
| parasite | 65 |
| pathogen | 52 |
| leishmania | 45 |
| cdv | 44 |
| canis | 34 |

**Table 8G – Higher Frequency Terms Linked**

**with the Central Term – Response: Tissue**

|  |  |
| --- | --- |
| **Term** | **Tissue** |
| cell | 467 |
| tumor | 181 |
| blood | 154 |
| lymphocyte | 111 |
| coronary | 78 |
| platelet | 76 |
| vascular | 63 |
| lesion | 59 |
| thyroid | 59 |
| brain | 57 |

**Table 8H – Higher Frequency Terms Linked**

**with the Central Term – Response: Treatment**

|  |  |
| --- | --- |
| **Term** | **Treatment** |
| clinic | 379 |
| dose | 195 |
| induce | 181 |
| vaccine | 98 |
| drug | 86 |
| vaccination | 71 |
| chemotherapy | 68 |
| stent | 63 |
| radiation | 47 |

**Table 8I – Higher Frequency Terms Linked**

**with the Central Term – Response: Outcome**

|  |  |
| --- | --- |
| **Term** | **Outcome** |
| immune | 523 |
| normal | 232 |
| inhibit | 102 |
| life | 98 |
| abnormal | 64 |
| survival | 61 |
| health | 55 |
| severe | 52 |

**Table 8J – Higher Frequency Terms Linked**

**with the Central Term – Response: Methods**

|  |  |
| --- | --- |
| **Term** | **Method** |
| assess | 119 |
| diagnosis | 76 |
| assay | 64 |
| ability | 58 |
| atopic | 53 |
| pathologic | 52 |
| analysis | 48 |
| histologic | 41 |

**How Authors Used Response Ideas**

Exhibit 1 shows sentences from a 2009 document that illustrates how the authors used ideas from the Cancer, Treatment, and Outcome dimensions. The ideas of interest were:

**CANCER TREATMENT OUTCOME**

**lymphoma clinic response**

**Hodgkin’s chemotherapy relapse**

**Exhibit 1. Sentences and Highlighted Terms Linked with Response – PMID 19999354.**

**Source:** [**Lawrence J**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Lawrence%20J%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**1,** [**Vanderhoek M**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Vanderhoek%20M%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**,** [**Barbee D**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Barbee%20D%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**,** [**Jeraj R**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Jeraj%20R%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**,** [**Tumas DB**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Tumas%20DB%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**,** [**Vail DM**](http://www.ncbi.nlm.nih.gov/pubmed/?term=Vail%20DM%5BAuthor%5D&cauthor=true&cauthor_uid=19999354)**. Use of 3'-deoxy-3'-[18F]fluorothymidine PET/CT for evaluating response to cytotoxic chemotherapy in dogs with non-Hodgkin's lymphoma.** [**Vet Radiol Ultrasound.**](http://www.ncbi.nlm.nih.gov/pubmed/?term=19999354) **2009 Nov-Dec;50(6):660-8 PMID: 19999354**

***Sentence 2: We evaluated prospectively the proliferation marker 3'-deoxy-3'[18F] fluorothymidine (FLT) in the context of FLT-PET/CT for detection of early response, confirmation of posttreatment response, and prediction of relapse in dogs with non-Hodgkin's lymphoma.***

***Sentence 19: FLT-PET/CT functional and anatomical imaging shows promise for the evaluation of response to cytotoxic chemotherapy in dogs with non-Hodgkin's lymphoma and for predicting relapse before standard clinical and clinicopathologic confirmation.***

**Exhibit 2. Sentences and Highlighted Terms Linked with Response – PMID 15835237.**

***Source:*** [***Wiedemann AL***](http://www.ncbi.nlm.nih.gov/pubmed/?term=Wiedemann%20AL%5BAuthor%5D&cauthor=true&cauthor_uid=15835237)***1,*** [***Charney SC***](http://www.ncbi.nlm.nih.gov/pubmed/?term=Charney%20SC%5BAuthor%5D&cauthor=true&cauthor_uid=15835237)***,*** [***Barger AM***](http://www.ncbi.nlm.nih.gov/pubmed/?term=Barger%20AM%5BAuthor%5D&cauthor=true&cauthor_uid=15835237)***,*** [***Schaeffer DJ***](http://www.ncbi.nlm.nih.gov/pubmed/?term=Schaeffer%20DJ%5BAuthor%5D&cauthor=true&cauthor_uid=15835237)***,*** [***Kitchell BE***](http://www.ncbi.nlm.nih.gov/pubmed/?term=Kitchell%20BE%5BAuthor%5D&cauthor=true&cauthor_uid=15835237)***. Assessment of corticosteroid-induced alkaline phosphatase as a prognostic indicator in canine lymphoma.*** [***J Small Anim Pract.***](http://www.ncbi.nlm.nih.gov/pubmed/?term=15835237) ***2005 Apr;46(4):185-90. PMID: 15835237***

***Sentence 6: It was found that sALP is not a useful prognostic indicator for response rate and remission duration in dogs with lymphoma.***

Exhibit 2 shows another example of authors’ use of the response ideas. That sentence linked terms from **Personal 🡪 Cancer 🡪 Outcome** dimensions. Exhibit 3 shows a third example of ideas involving response. The dimensions involved were – **Personal 🡪 Cancer 🡪 Treatment 🡪 Outcome.**

**Melanoma, Vaccine, Response Ideas:** Table 9 shows the history of studies reporting a relationship between melanoma (Cancer Dimension), vaccine (Treatment Dimension), and response (Outcome Dimension). The earliest study was entered into PubMed in 1999 and the latest in 2014. The table reports the two primary reference elements – the source data (journal publication date and identifiers) and the PubMed Identification number (Ident). The latter is the most efficient for retrieval of specific documents.

**Table 9. Studies Considering the Relationship between Melanoma, Vaccine, Response in Dogs.**

|  |  |
| --- | --- |
| **Source** | **Ident** |
| [Cancer Gene Ther. 1999 Jan-Feb;6(1):26-36.](http://www.ncbi.nlm.nih.gov/pubmed/10078961) | 10078961 |
| [Clin Cancer Res. 2003 Apr;9(4):1284-90.](http://www.ncbi.nlm.nih.gov/pubmed/12684396) | 12684396 |
| J Vet Intern Med. 2005 Jan-Feb;19(1):56-63. | 15715049 |
| Cancer Immunol Immunother. 2006 Apr;55(4):433-42. | 15965647 |
| Cancer Gene Ther. 2006 Oct;13(10):905-18. | 16710345 |
| Mol Ther. 2007 Nov;15(11):2044-50. | 17726460 |
| Am J Vet Res. 2011 Dec;72(12):1631-8. doi: 10.2460/ajvr.72.12.1631. | 22126691 |
| Vet J. 2013 Oct;198(1):28-33. doi: 10.1016/j.tvjl.2013.06.005. | 23850019 |
| Clin Cancer Res. 2014 Jul 15;20(14):3753-62. doi: 10.1158/1078-0432.CCR-13-3042. | 24874834 |
| Expert Opin Biol Ther. 2014 Oct;14(10):1427-42. doi: 10.1517/14712598.2014.927433. | 25023219 |

**Protocol Development**

The research design template provides an outline of the elements needed in developing a plan of conduct (i.e., protocol). The template approach can be employed to develop and evaluate various research strategies. As such, it is useful in the cognitive process leading to effective generation of new knowledge. It is a form of simulation enabling the analyst to visualize the system that will be transformed into specific procedures by the construction of the research protocol. That outline is:

1. ***Recruitment of study participants***. The Personal Dimension provides the details needed in describing the participants. Mechanisms to accomplish recruitment of potentially eligible individuals need to be developed.
2. ***Establishment of Eligibility***. The Subject Dimension provides the details needed in determining the entry status of each participant.
3. ***Assignment to Treatment***. The Treatment Dimension provides the details needed in assigning study participants to the treatments being studied.
4. ***Selecting Outcomes***. The Outcome Dimension provides the details needed in determining the effects of the treatments.
5. ***Selecting Methods***. The Methods Dimension provides the details needed in choosing the methods used in recruitment, eligibility, treatment, and outcome.

The central database and the higher cognitive function algorithms create a different type of expert. Traditionally, a specialist would be chosen for his/her wisdom and opinions. With the tools described above, the expert is needed to clarify and expand the higher cognitive functions while the more clerical/mechanical ones are converted to a transparent, evidence-based system. By making the analysis transparent and quality-controlled, the needed documentation is readily available. This facilitates the shift to true intellectual prowess by the expert. In a similar fashion, the student, new to the subject, can begin learning by solving problems and by building new idea structures. The ability to acquire, organize, and utilize the ideas enhances the transformation from novice to professional. The need to spend long hours in the library stacks is replaced by a need to spend time thinking and researching. Those actions could yield an operational description of critical and creative thinking.

With the ideas organized and usable, students can build numerous idea structures representing a given topic. This array shifts the focus from a single answer to a spectrum of possibilities each with desirable and undesirable characteristics. Weighing those attributes and developing rationales is an example of the critical thinking process. Translating those functions to transparent, quality-control procedures is an example of the Idea Analysis approach.