Cognitive Tasks involved in carrying out experimental research

** This summary was derived from a fuller Cognitive Task Analysis of experimental research, as suggested by Carl Wieman. For a more complete description, see Carl's original document.*

1. **Establishing research goal**: What are the goal(s) and question(s) of the research?[1]
   a. Deciding if the goal is interesting, timely, worthwhile, etc.
   b. Predicting if the goal is sufficiently ahead of current knowledge to be interesting but not so far ahead that it might have too high a risk or failing or be ignored.
   c. Evaluating whether the research question is consistent with the constraints on funding, time, equipment and laboratory capacity, including personnel.

2. **Defining criteria for suitable evidence**: Deciding what will constitute suitable evidence to achieve the goal by developing and/or utilizing existent criteria
   a. what data would be convincing given the state of the field,
   b. what variables are important and how they might be measured and controlled,
   c. what types of experimental controls and checks would need to be in place.

3. **Determining feasibility of experiment**:
   a. Predicting whether or not it is realistically possible to carry out the experiment, and, if it is, analyzing the scale of time and money required and deciding if these are reasonable. (more detailed reiteration of 1.c.)
   b. The researcher must also analyze contingency options, if the results of the experiment are not what is hoped for (what other significant results could be produced by the apparatus or a "failed" experiment?).

4. **Experimental design**:
   a. Exploration of many possible preliminary designs (requires clear definition of the optimum depth of analysis of the alternative designs)
   b. Analyzing relevant variables that may lead to systematic errors in results and interpretation. This requires having complex cause and effect models for the experiment. (will be repeated after measuring performance of apparatus)
   c. Finalizing the design, taking into account construction details and performance requirements of each component. Often requires bringing in additional expertise.
   d. Developing detailed data acquisition strategy: How much data to take and over what parameter ranges, how long to accumulate data in each measurement, in what order are things measured, which measurements do you repeat and how often. Deciding on required precision and accuracy. This includes deciding which quantities need not be measured. This must take into account constraints on time, clarity of results, all potential statistical and systematic uncertainties, and the importance and requirements for distinguishing between different potential interpretations of results. (this step repeated/revised after performance of apparatus has been measured)

5. **Construction and testing of apparatus**: [1,2]
   a. Deciding who should build the various parts and on what schedule. (in-house, purchase standard parts, special construction by outside companies, …?) Requires evaluation

and application of tradeoffs of cost, construction expertise, time, degree of confidence as to specific design details.

   b. Developing criteria and test procedures for evaluation of the apparatus components as they are completed.
   c. Collecting data on performance of specific components and full apparatus.
   d. Develop procedures for tracking down the source of malfunction when the individual components or the assembled apparatus do not perform as designed. This necessarily involves deep familiarity with the respective hardware and a repertoire of trouble-shooting regimes that are highly specific to the field, the apparatus, and the approach being used.) [2]
   e. Figure how to modify particular parts, or overall apparatus, according to test results.
   f. Reiterate data acquisition strategy 4.d., taking into account actual performance of finished apparatus.
   g. (after completion, collect experimental data)

6. **Analyzing data**:
   a. Modeling the data by suitable mathematical forms, including deciding which approximations are justified and which are not.
   b. Deciding on what statistical analysis methods and procedures are appropriate.
   c. Calculating statistical uncertainty.

7. **Evaluating results**: [1, 2]
   a. Checking the results, when they come out differently than expected. This involves calling on complex mental models incorporating a web of cause and effect relationships, strategies for separately relevant and irrelevant information, complex pattern recognition and search algorithms. (Also usually involves extensive additional data collection, and possible modification of apparatus and redoing data collection.)
   b. Testing data that comes out as expected. Identify redundant tests for possible systematic errors, being particularly sensitive to experimenter biases.

8. **Analyzing implications if novel**:
   a. What are plausible interpretations or new theoretical or experimental directions implied by these results? [1]

9. **Presenting the work**:
   a. Follow standard data display procedures, or as needed, develop new procedures that highlight critical features of methods or results.
   b. Explaining the work so the broader context and uniqueness of the work, the apparatus, the procedures, and the conclusions are easily understood, and the audience/readers perceive it to be of maximum interest and significance.

[1] Requires extensive expertise in the research field.
[2] Requires extensive experience with the relevant equipment.