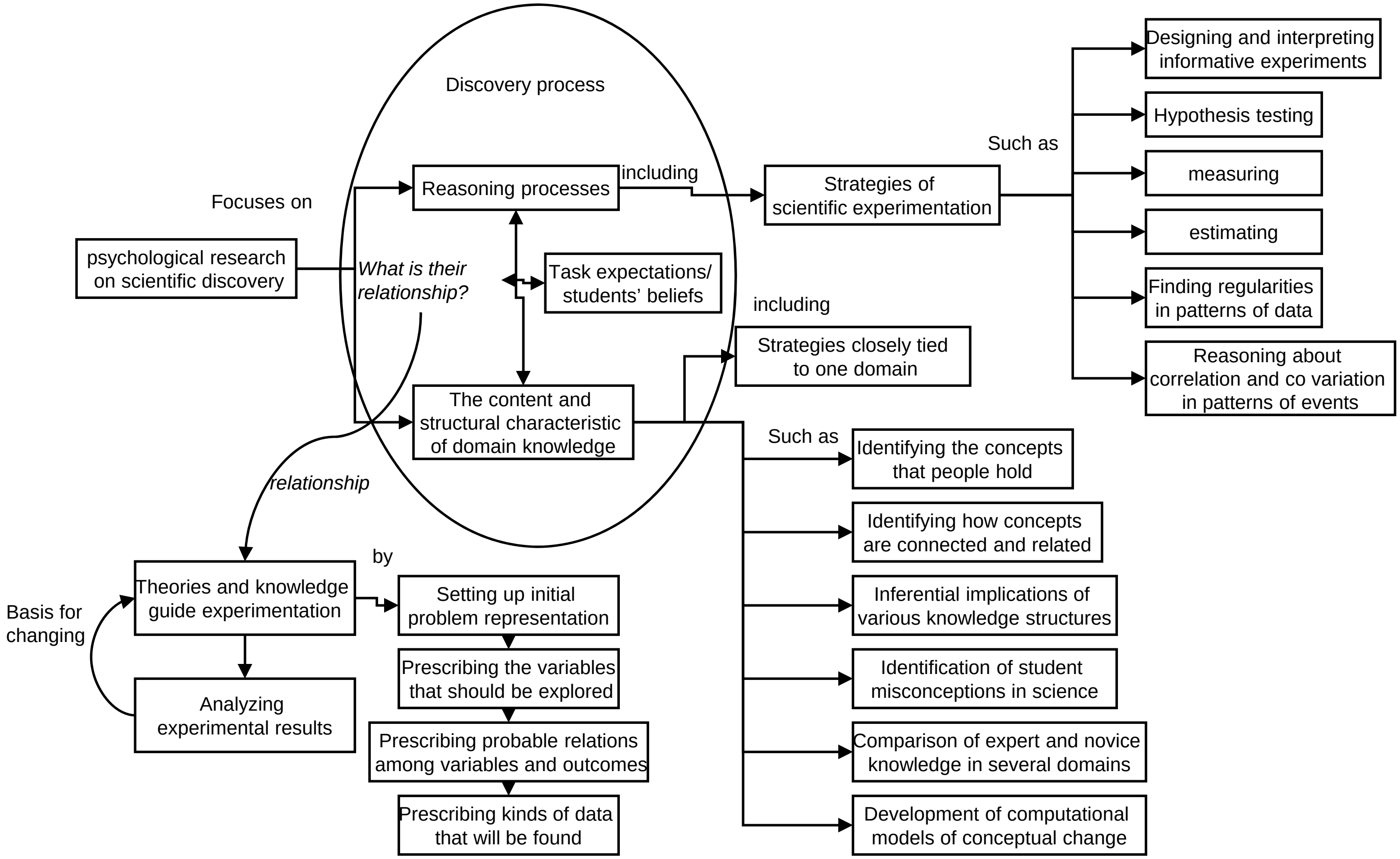
Schauble, L.; Glaser, R.; Raghavan, K. & Reiner, M.
Causal Models and Experimentation Strategies in Scientific Reasoning
The Journal of the Learning Sciences, Lawrence Earlbaum, **1991***, 1*, 201-238



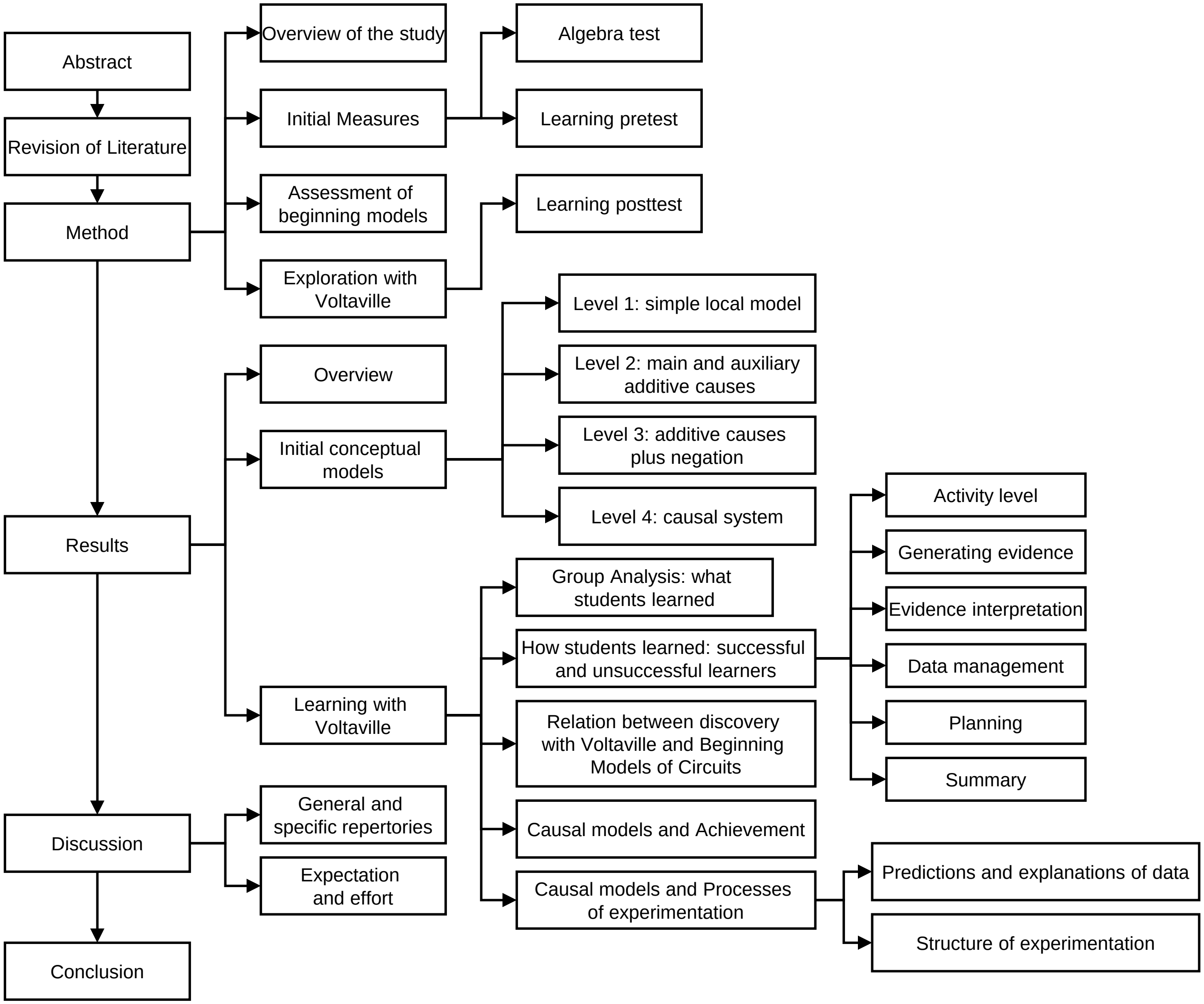
Purpose of the study	Hypothesis	Participants	Instruments and Data Analysis	Design and Procedures	Findings
The overall goal of this study was to construct a picture of the reciprocal influences of strategy on knowledge and knowledge in strategy by focusing on a topic in which individuals have some beginning conceptions but then engage in self-directed experimentation to confirm, extend, to change those beginning theories (p.203). Rather than studying the products of conceptual change, here we observe how good and poor students negotiate the coordination between evolving knowledge and strategic deployment. The study concerns relations between theory and experimental strategies, identifying some experimentation strategies that are specific to the topic being explored and others that have more general applicability.	It is not directly stated. However I believe this might be their hypothesis: However, more fundamentally, we believe that experimentation affords a rich context for studying the process of theory change, which is central to learning in general, whether it takes place in the classroom or elsewhere (p.203). For this study, our interest is in diagnosing student causal models and then exploring whether these causal models are associated with performance in a second experimentation task, work with the computer circuit laboratory (p221). Here we report only those results pertinent to the knowledge representation or causal models that students applied in solving the problem. Recall that the major question in this study concerns relations between these causal models and students' strategies for self-directed experimentation with the computer laboratory. (p. 214)	22 University of Pittsburgh undergraduate volunteers (16 men and 6 women) who where not majoring in science and who had had no formal college instruction in physics.	The study included several instruments: Algebra pretest.- to identify students' ability to solve simple algebraic equations. Learning pretest- consisted of two parts: a) circuit laws and concept (open-ended) questions. b) A multiple-choice qualitative problems assessing commonly held conceptions about circuits. The authors did not discuss their validity and reliability of their instruments. Not mentioned in the methods sections, two more instruments were identified. In addition, the authors analyzed the students' notes made on the software. These notes included students' hypothesis, either a qualitative statement constructed from a dictionary of phrases, or an algebraic expression constructed from a list of variables and operators. Also sessions were videotaped where students interacted with the simulation tools and their interaction with the experimenter. The experimenter occasionally prompted students to say what they were thinking, to explain the basis for a conclusion or to talk through a numerical calculation. The authors did not describe how the data was coded. They actually did p. 211: all student protocols were sorted independently by two judges into four categories that form the basis for their description of the students' models (full details in press). However, in the data analysis section the authors do provide excerpts of their conversations with students. Data analysis was done by using descriptive statistics and by computing t test to identify if there was an effect caused by the computer laboratory experience. The results were reported in terms of p-values.	The students participated in six individually-administered weekly sessions lasting 1.5 hours each. The first session was devoted to tow pretest measures. In the second session, students worked on a problem designed to assess students' uninstructed naïve models about electric circuits and circuit components. The third fourth and fifth sessions entailed work with the computer laboratory to rediscover the principles of electric circuits. The final session was a learning posttest.	The authors focused their description of their findings in four main areas a) Conceptual (causal) models in which they identified four levels. The lower-level models classify material in the task by their surface features and the higher-level models focus on the relevant functions of the components. In general, students with better models of circuits also tended to use more appropriate and more effective strategies for evaluating evidence. b) Students' performance (pre and post tests) Students holding the more sophisticated causal models achieved better overall success in solving the problem. c) Strategies on how students learned The authors identified that competence at simple algebraic manipulation differentiated the good from the poor learners, concluding that algebraic competence ma served as a domain-general tool that supports discovery learning. They also pointed out that because even the poor learners correctly answered about ¾ of the items correct, it is unlikely that algebra knowledge alone accounted for the learning differences. d) Strategies of experimentation The authors discussed five classes of student behaviors: activity level, evidence generation, evidence interpretation, data management, and planning. These results indicate that there is a relation between holding more sophisticated qualitative models about circuits and learning in the open ended discovery laboratory Students with more elaborated and sophisticated causal models made more substantial learning gains, both in recalling and applying the principles they discovered with the computer laboratory and in making inferences beyond the principles learned. (p.225) Those students who held the higher level causal models, however learned more. Furthermore, those students who learned more spontaneously used experimentation strategies that the poorer students did not employ regularly. Role of the student causal models in supporting the experimentation strategies: *Predictions and explanations* of the poor learners were less supportive of reasoning. For the case of *structure and experimentation*, those students with the more sophisticated causal models explored the space of possible experiments both more broadly and more deeply. They persisted in trying to learn as much as they could about a particular type of circuit rather than jumping form case to case. When they identified a relation, they tested its generality rather than abandoning the idea for a new one (p.230). When students enter an exploratory situation, they import some representation of the problem into their solution activity. In this case, these representations appear to take the form of causal models, Which are related to amount of learning achieved, predictions and explanations of the data and the structure of experimentation. (233) The authors reported that the strategies that best differentiated effective from ineffective learning were those concerned with interpreting evidence, generating alternative hypotheses and finding regularities in quantitative data (p 234) When compared their findings with similar studies, the authors suggested that possible differences may be due to differences in subject matter. But also, they discussed that there are strategies associated with success in both domains as well (e.g. systematicity of data recording, students being aware of their strengths and limitations and recalling information, and of how to use and manage external records, manipulation of one variable at a time). The authors briefly discuss students' expectations.

a1

Slide 2

a1 Like Klahr and Simon's representation space

admagana, 7/18/2008


Abstract
Revision of Literature
Method
Overview of the study
Initial Measures
Assessment of beginning models
Exploration with Voltaville
Algebra test
Learning pretest
Learning posttest
Results
Overview
Initial conceptual models
Level 1: simple local model
Level 2: main and auxiliary additive causes
Level 3: additive causes plus negation
Level 4: causal system
Learning with Voltaville
Group Analysis: what students learned
How students learned: successful and unsuccessful learners
Activity level
Generating evidence
Evidence interpretation
Data management
Planning
Summary
Relation between discovery with Voltaville and Beginning Models of Circuits
Causal models and Achievement
Causal models and Processes of experimentation
Predictions and explanations of data
Structure of experimentation
Discussion
General and specific repertories
Expectation and effort
Conclusion

Appendix A: Summary of results for the article Schauble et al. 1991

Summary of Results		
Initial conceptual models Data source and analysis: detailed analysis of 10 of the 22 protocols. General findings: Identification of a set of criteria that differentiated among four major ways of representing the materials in task. The students who developed better models tended to use more appropriate and effective strategies for generating and evaluating evidence.	Level 1: simple local model Students made literal interpretations of simple causes: things that worked and things that didn't work. Five of the 22 students performed at this level	
	Level 2: main and auxiliary additive causes Students identified two kinds of component functions: those that work and those whose function is to help. Two of the 22 students performed at this level	
	Level 3: additive causes plus negation Students identified that positive and negative levels of the outcome wore possibilities 12 of the 22 students performed at this level	
	Level 4: causal system Students at this level recognized that any outcome depended on the interaction of all variables of the model. Three of the 22 students performed at this level	
Learning with Voltaville	Group Analysis: what students learned The average learning from pretest to posttest was 18 percentage points. The authors conducted a t-test and reported the p-value showing that the treatment had an effect. t(21)=4.7, p<.001. Then the authors went into a deeper level of analysis identifying in which areas most of the gain occurred.	
	How students learned: successful and unsuccessful learners The authors divided the students in two groups according to their performance. A group of 7 poor learners who did not achieve any gains and a group of 7 good learners whose gain scores were higher than the group median (34.5). The authors also reported that the poor and good learners performed equally in the pretest but differently in the posttest. They reported those differences in terms of t-tests and p-values for the concept questions and the circuit problems.	Activity level.- in this section the authors explored if the sheer amount of information produced by the students should be associated with greater learning. The authors identified three indices: the total number the circuits each student constructed and students' tendency to be thorough and systematic about taking measures. The good ant the poor learners appeared to be reasonably motivated and actively seeking information.
		Generating evidence.- In this section the authors explored if effectiveness of experimentation is constrained by the informativeness of the evidence generated by students. The computer records were used for exploring: kinds of information generated, the order in which evidence was generated and control of variables in experimentation. The authors found that a) most of the students in both groups explored a reasonable number of the models in a relatively systematic manner, b) the good learners used the strategy of controlling one variable at a time, which provided good students a significant advantage in discovering the laws.
		Evidence interpretation.- the authors considered four factors for this area: a) number of total hypotheses stated, b) percentage of hypotheses that were correct, c) students' overall success in finding the circuit laws, and d) the percentage of the goals that were supported by evidence judged sufficient by the criteria of the software program's rules. The authors reported the following findings. The good learners stated more hypotheses than the poorer one, a larger percentage of the good learners' hypotheses were correct, the good learners were more successful in identifying the circuit laws and the good learners reported more average number of goals than the poorer ones.
		Data management.- explored if strategies of students' data management skills is associated with more successful performance. The researchers found that although the good learners were more likely to keep systematic records, doing so was not necessarily or sufficient for success in the activity.
		Planning.-The authors wanted to identify if on what did the students put particular focus in their planning. They found that a few students concentrated excessively on the execution of local procedures while some others realized that their procedures should be focused on the search for laws and relations. For this purpose the authors used the tape-recorded protocols The authors found that the majority of the plans conducted by students were at the local and task-oriented level (see Table 2 p. 222), however the authors did found a second group of students who planned at the goal-oriented level. Through the t-test applied the authors concluded that goal-oriented group achieved significantly higher posttest scores than the local, task-oriented group.
	Relation between students' causal models and the amount of learning achieved.- five of the seven poor learners held the lower-level qualitative models and two held at level 3. For the case of the good students, four students performed at level 3 and the other three performed at level 4. Fisher's test indicated that good learners were more likely to hold at the higher levels while the poorer ones were liable to hold one of the two lower ones. The authors concluded that student who elaborated more sophisticated causal models made ore substantial learning gains in recalling and applying the principles they discovered with the software tools, and in making inferences beyond those principles learned	
	Influence of the causal models on the processes of experimentation	Exploration of the kinds of predictions and explanations made by students.- The predictions and explanations of the poorer learners were less supportive for reasoning compared to the better ones. This was due to the fact that the less advanced levels appeared to guide students to look for information in the wrong places; leading to misunderstandings about the function of the component and in the interpretation of results.
		Description of how causal models affected the overall structure of student experimentation.- Those students who performed at a higher level on their progression of causal models explored the space of possible experiments in a more broadly and deeply manner. They persisted in their testing of experiments.