Cognitive models
- Drive instructional decisions for automated tutoring
- Appear critical to accurate assessment of self-regulated learning skills or motivational states.
- Educational data mining provides an opportunity to improve models through discovery.
- A correct cognitive model is one that is consistent with student behavior.

Representing Knowledge Components as factors of items
- Problem: How to represent KC model?
- Solution: Q-Matrix (Tatsuoka, 1983)

Components as factors of items
- Problem: How to represent KC model?
- Solution: Q-Matrix (Tatsuoka, 1983)

Representing Knowledge
- Statistical model
- A correct cognitive model is one that is consistent with student behavior.

Additive Factors Model
- Problem: How to predict student responses from model?
- Solution: Additive Factor Model

Logistic regression to fit learning curves (Draney, Wilson, Pirolli, 1995)

Fitting models
- How to compare cognitive models?
  - A good model minimizes prediction risk by balancing fit with data & complexity (Wasserman 2005)
- Model-data fit metrics
  - Log likelihood, root mean squared error (RMSE), mean average deviation (MAD), area under curve (AUC), ...
- Prediction metrics
  - BIC, AIC: Faster metrics add a penalty for # parameters
  - Cross validation: Slower but better

Learning Factors Analysis (LFA)
- Method for discovering & evaluating cognitive models
- Finds knowledge components that best predict student performance & learning transfer
- Inputs
  - Data: Student success on tasks in domain over time
  - Codes: Factors hypothesized to drive task difficulty & transfer
- Outputs
  - A rank ordering of most predictive cognitive models
  - Parameter estimates for each model

How to improve existing cognitive model?
- Have experts look for difficulty factors that are candidates for new KCs. Put these in “P matrix”

Using P matrix to update Q matrix
- Create a new Q' by using elements of P as arguments to operators
  - Add operator: Q' = Q + P[,1]
  - Split operator: Q' = Q[,2] * P[,1]

LFA: KC Model Search
- How to find best model given Q and P matrices?
  - Use best-first search algorithm (Russell & Norvig 2002)
  - Guided by a heuristic, such as BIC or AIC
  - Do model selection within space of Q matrices

Conclusions
- This research can be used to discover better cognitive models.
  - Better cognitive models can be used to redesign instruction
    - Better problem selection
    - Creating new tasks
    - Create better hints
    - Redesign instruction more generally