Predicting Patterns in Education: Linking Theory to Practice

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Overview
- Problems in linking theory to practice
- A different perspective for measurement and analysis: MAPSAT
- Examples of practical results from studies using MAPSAT methods
- APT for temporal patterns
- APC for structural patterns
- MAPSAT software under development

Problems in Linking Theory to Practice: Some Indicators

- Educating School Leaders (Levine, 2005): "Educational administration scholarship is ... disconnected from practice." (p. 5)
- Educating School Teachers (Levine, 2006): "Across [teacher education] programs there is a chasm between theory and practice." (p. 4)

Problems in Linking Theory to Practice: Some Indicators

- Imagine if medical doctors practiced medicine without regard to research in medical science
- Yet, apparently most teachers and administrators practice and lead P-12 education with little regard for research in education (Levine, 2005; 2006; Zirkel, 2007)
An Alternative

- My experience in Project PRIME in Texas revealed inadequacies of linear models approach (1972-1975)
- I invented Analysis of Patterns in Time (APT) to help identify predictable sequences of events that can inform educational practice (1976-1980)

MAPSAT: APT & APC

- Ken Thompson developed Analysis of Patterns in Configurations (APC) from Axiomatic Theories of Intentional Systems (ATIS) to measure structural properties (2006)
- APT & APC now called MAPSAT: Map & Analyze Patterns & Structures Across Time

MAPSAT Methods

- Basic assumption:
  Observed events can be mapped into categories in classifications.
- Major difference:
  Measure the relation vs. relate the measures.

Examples of Studies Using MAPSAT Methods

- Teaching and learning quality
- Activity structures in a Montessori class
- Patterns of mode errors by computer users of graphical interfaces
- Computer-Adaptive Mastery Testing
- Academic learning time

Teaching and Learning Quality

(Frick, Chadha, Watson, Wang & Green, 2007)

- Is there a relation between student ratings of college courses and learning achievement?
- Can we create better course evaluation instruments which are more strongly related to student learning achievement?
Teaching and Learning Quality
(Frick, Chadha, Watson, Wang & Green, 2007)

First Principles of Instruction (Merrill, 2002)
- **Authentic Problems/Tasks**: students engage in real-world, authentic problems or tasks
- **Activation**: student prior learning or experience is connected to what is to be newly learned
- **Demonstration**: students are exposed to examples of what they are expected to learn or do
- **Application**: students try out what they have learned, with instructor coaching, scaffolding or feedback
- **Integration**: students incorporate what they have learned into their own personal lives

Learning Progress: student self-perception of how much she or he has learned (cf. Cohen, 1981) (indicator of Kirkpatrick Level 2 evaluation)
Student Satisfaction: with course and instructor (Kirkpatrick Level 1 evaluation)
Overall course/instructor quality (Cohen, 1981; BEST items 1-3)

Web survey of 193 respondents from multiple institutions (2/3 not at IU IP numbers)
At least 111 different courses and instructors rated in a wide range of subjects in business, medical sciences, liberal arts, education, and information technology
About 2/3 undergraduate and 1/3 graduate level
Undergrads represented fairly evenly from freshmen through seniors
Scale reliabilities very high: .82 to .97 (Cronbach α’s)

APT Results for the Pattern: If ALT and First Principles, then Outstanding Instructor/Course

<table>
<thead>
<tr>
<th>ALT Agreement</th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined/First Principles Agreement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>Yes</td>
<td>4</td>
<td>12</td>
</tr>
</tbody>
</table>

Global Rating Agreement Count
- No: 31
- Yes: 12

Mastery Level Count
- Nonmastery: 14
- Partial: 19
- Mastery: 20

Summary: If students agreed that both First Principles and ALT occurred (vs. disagreed):
- They were 9 times more likely to rate a course and instructor as outstanding.
- They were 5 times more likely to report mastery of course objectives.
Student Autonomy Support and Activity Structures in a Montessori Class
(Koh & Frick, 2007)

- Case study of upper elementary Montessori classroom in Spring 2006
- Ethnographic field notes collected (10 observations about 1 hr. each)
- Two major types of activity structures:
  - Head problems (in math)
  - Morning work period (Montessori works)

Head Problems: teacher-created math problems given to whole class to work on individually (about 1 hr.)

Morning Work Period: students choose individual Montessori works from classroom learning environment (about 3 hrs.)

Affect Relation: ordered pair in set theory, with a predicate: \( P(x,y) \).

Components \( x \) and \( y \) could be individual teachers, students, works (Montessori designed), computers, etc.

‘Support’ affect relation \( (x,y) \): \( x \) supports the learning of \( y \)

‘Choice’ affect relation \( (x,y) \): \( x \) chooses learning activity \( y \)

18 structural properties of affect relation sets:
- Active dependence
- Centrality
- Complexity
- Independence
- Interdependence
- Complete connectivity
- Etc.

Analysis of Patterns in Configurations: ‘Support’ affect relations

Example of ‘Support’ affect relations

\( \{s1,s2\} \) (s2,s1)(t2,s1)
Patterns of Mode Errors in Human-Computer Interaction (An, 2003)

- Mixed methods approach
- 16 college students performed 8 computer tasks with 3 modern GUI interfaces (word processor, address book, image editor).
- Participants were videotaped, and stimulated-recall interviews conducted immediately afterwards.
- Content analysis revealed 3 types of mode errors.

Patterns of Mode Errors in Human-Computer Interaction (An, 2003)

- Source of error analysis revealed that mode errors appeared to result from 8 types of design incongruity:
  - Unaffordance
  - Invisibility
  - Misled expectation
  - Unmet expectation
  - Mismatched expectation
  - Inconsistency
  - Unmemorability
  - Over-automation

Patterns of Mode Errors in Human-Computer Interaction (An, 2003)

- Consequences of mode errors:
  - Can't find hidden function
  - Can't find unavailable function
  - False success
  - Stuck performance
  - Inhibited performance
  - Inefficient performance

Computer-Adaptive Mastery Testing (Frick, 1992)

- Item Response Theory (IRT) requires 500 – 1000 examinees to estimate a, b, and c parameters before CAT can be used
- IRT not practical for mastery testing in instructional settings
- Can we still do CAT effectively by another approach?
- What if APT is used to form expert systems rules (in contrast to ICC in IRT)?
Computer-Adaptive Mastery Testing (Frick, 1992)

Use APT to form 4 rules (patterns) for each test item - needed about 50 examinees (25 masters and 25 nonmasters) for stable estimates

- Rule i.1: If the examinee is a master and item i is selected, then the probability of a correct response is \( P(C_i | M) \).
- Rule i.2: If the examinee is a master and item i is selected, then the probability of an incorrect response is \( P(\neg C_i | M) \).
- Rule i.3: If the examinee is a nonmaster and item i is selected, then the probability of a correct response is \( P(C_i | \neg M) \).
- Rule i.4: If the examinee is a nonmaster and item i is selected, then the probability of an incorrect response is \( P(\neg C_i | \neg M) \).

EXSPRT with APT rules can do intelligent item selection and shorten length of mastery tests
EXSPR-based CAT similar to IRT-based CAT in terms of test lengths and decision accuracy (Frick, 1990; 1992; Welch & Frick, 1993; Luk, 1994)
EXSPRT more practical in instructional settings, since only 50 examinees are needed vs. 500-1000 for IRT item parameter estimation

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Academic Learning Time Study (Frick, 1990; 1983)

- 25 systems observed in central and southern Indiana
- Tracked 25 target students in academic activities over several months for 8-10 hours each
- Trained observers coded types of academic learning contexts, task difficulty and task success
- Observers also coded student and instructor behaviors in math and reading (about 500 time samples at one-minute intervals for each target student)
- Nearly 15,000 time moments sampled overall

What observers coded in math and reading activities each minute

- Types of student engagement: written, oral, and covert on-task; off-task behaviors (later recoded as engagement, EN, and non-engagement, NE)
- Types of instructor behaviors: structuring, explaining, demonstrating, questioning, feedback (later recoded as direct instruction, DI), and monitoring academic seatwork (non-direct instruction, ND)

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Standard analysis: columns 1 and 2: independent measures of DI and of EN were correlated (n = 25)

<table>
<thead>
<tr>
<th>( p(DI) )</th>
<th>( p(EN) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.39</td>
<td>0.60</td>
</tr>
<tr>
<td>0.39</td>
<td>0.60</td>
</tr>
<tr>
<td>0.37</td>
<td>0.62</td>
</tr>
<tr>
<td>0.32</td>
<td>0.45</td>
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<td>0.32</td>
<td>0.45</td>
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<td>0.32</td>
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</table>

Mean (SD)

Linear Models Approach

- Linear models approach (quantitative method):
  - Relates independent measures through a mathematical function
  - Treats deviation from model as error variance

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Linear Models Approach cont’d

Analysis of Patterns in Time

- APT measures a relation directly by counting occurrences of when a temporal pattern is true or false in observational data
- Probability of joint or sequential occurrence can be estimated for a pattern from the counts

APT Results

- Means and standard deviations for the relations
- Mean $p(EN \mid DI) = 0.967$ s.d. = 0.029
- Mean $p(EN \mid ND) = 0.573$ s.d. = 0.142
- When direct instruction is occurring, students are highly engaged.
- When non-direct instruction is occurring they are less engaged.
- Students were 13 times more likely to be off-task during non-direct instruction compared with direct instruction: $(1 - 0.573) / (1 - 0.967) = 12.94$.

LMA vs. APT

- Linear models relate the independent measures by a function for a line:
  - e.g., $EN = 0.57 + 0.40DI$
- APT measures the relation in terms of joint, conditional, or sequential occurrence:
  - e.g., $p(EN \mid DI) = 0.967$
  - e.g., $p(EN \mid ND) = 0.573$

\[ DI = \text{direct instruction}, \quad EN = \text{student engagement}, \quad ND = \text{non-direct instruction} \]
APT: Analysis of Patterns in Time

How it works

APT Methodology: sequential occurrence
- When one event precedes another, and when observers code the order in which events occur:
  - APT can estimate the probability of the consequent following the antecedent event.
  - APT can estimate likelihoods of sequences longer than two (unlike Markov chains).
  - APT can estimate both joint and sequential event occurrences in complex combinations.

APT Coding (temporal configuration)

<table>
<thead>
<tr>
<th>Clock Time</th>
<th>Target</th>
<th>Instruction</th>
<th>Student Engagement</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:01</td>
<td>Mona</td>
<td>Direct</td>
<td>Off-task</td>
</tr>
<tr>
<td>9:02</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:03</td>
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<td>9:04</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>9:06</td>
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<td></td>
<td>Off-task</td>
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<tr>
<td>9:07</td>
<td></td>
<td></td>
<td>On-task</td>
</tr>
<tr>
<td>9:08</td>
<td></td>
<td>Non-Direct</td>
<td></td>
</tr>
<tr>
<td>9:10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9:11</td>
<td></td>
<td></td>
<td>Off-task</td>
</tr>
<tr>
<td>9:12</td>
<td></td>
<td>Null</td>
<td>Null</td>
</tr>
</tbody>
</table>

APT Classifications and Categories
- Each column is a classification
- Classifications co-exist in time
- Categories of events within a classification cannot co-exist in time (since they are mutually exclusive, by definition)
- An observer codes event changes within each classification in the order that they occur.
- Date/time is always a classification and is recorded whenever there is an event change.

Example of sequential coding with three classifications

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APT Query: IF target student IS Mona?

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<td>9:13</td>
<td></td>
<td>Null</td>
<td>Null</td>
</tr>
</tbody>
</table>
APT Query and Results

**Query**

IF target student IS Mona?

**Results**

Cumulative duration = (9:13 - 9:01) = 12 minutes
Cumulative frequency = 1 event
Likelihood = 1 out of 1 relevant event changes = 1.00
Proportion time = 12 minutes out of 12 = 1.00

---

APT Query Results

**Query**

IF target student IS Mona AND instruction IS direct?

**Results**

Cumulative duration = (9:08 - 9:01) = 7 minutes
Cumulative frequency = 1 event
Likelihood = 1 out of 2 relevant event changes = 0.50
Proportion time = 7 minutes out of 12 = 0.583

---

APT Query Results

**Query**

IF target student IS Mona AND instruction IS direct, THEN student engagement IS on-task?

**Results**

Cumulative duration = (9:06 - 9:03) + (9:08 - 9:07) = 4 minutes
Cumulative frequency = 2
Likelihood = 2 out of 4 = 0.50
Proportion time = 4 minutes out of 6 = 0.667

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APT Query Syntax
APT Syntax (cont’d)

APT Query Syntax

- Thus, simple to very complex temporal patterns can be specified within APT queries.
- Joint and/or sequential occurrences of events can be specified.
- Results include frequency counts, likelihood estimates, durations and proportions of total time.

APC: Analysis of Patterns in Configuration

Familiar Patterns: Structural

- Geographical relation:
  - Bloomington is south of Indianapolis.
  - Martinsville is south of Indianapolis.
- Organizational relation:
  - Gerardo Gonzalez is University Dean of the School of Education who supervises:
    - Peter Kloosterman, Executive Associate Dean, SoE, IUB campus
    - Khaula Murtahda, Executive Associate Dean, SoE, IUPUI campus
Affect relation set: guides research of

Professor Reigeluth

Professor Boling

Kurt

Sunny

Marisa

Nichole

Old IST Ph.D. structure

Affect relation set: guides research of

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Marisa

Nichole

New IST Ph.D. structure

APC allows us to measure structural properties of digraphs

<table>
<thead>
<tr>
<th>Property</th>
<th>Count</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Dependence</td>
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<td>5.97</td>
</tr>
<tr>
<td>Centrality</td>
<td>4.00 paths</td>
<td>21.89</td>
</tr>
<tr>
<td>Compactness</td>
<td>9.00 paths</td>
<td>51.76</td>
</tr>
<tr>
<td>Complete Connectedness</td>
<td>0.00 paths</td>
<td>0.00</td>
</tr>
<tr>
<td>Complexity</td>
<td>5.00 paths</td>
<td>5.00</td>
</tr>
<tr>
<td>Etc.</td>
<td>Etc.</td>
<td>Etc.</td>
</tr>
</tbody>
</table>

Structural Property Definition

Example: Interdependence

\[ \text{Interdependence} = \sum_{i=1}^{n} \sum_{j=1}^{n} \left| \text{init}(i,j) \cap \text{recep}(i,j) \right| \]

Egads – this could be very tedious and hard to do by hand!

MAPSAT Software for Researchers

- Create your own classifications and categories
- Code temporal events and affect relations
- Analyze temporal sequences
- Analyze structural properties
MAPSAT: Map & Analyze Patterns & Structures Across Time

Summary

MAPSAT Summary
- Basic assumption: Observed events can be mapped into categories in classifications.
- Major difference: Measure (or Map) the relation vs. relate the measures.
- MAPSAT includes APT and APC methods

MAPSAT Summary
- The value of MAPSAT methods was illustrated by results from five empirical studies.
- These results have direct implications for practice.
- Software is under development to do MAPSAT.

Questions
For more information on MAPSAT and references for past research studies:

http://www.indiana.edu/~tedfrick