AECT Virtual Presentation, Las Vegas, NV, USA

Analysis of Patterns in Time (APT): A Fruitful Methodology for Investigating Learning Journeys in Education

Ted Frick

Professor Emeritus
Indiana University

Oct. 26, 2022

Go to https://mapsat.iu.edu for a recording of the full presentation

Alternate Title

What they didn't teach you in graduate school courses on educational research methods: Analysis of Patterns in Time

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Biggest Adopters of Analysis of Patterns in Time—thus far

- Google Analytics
- Major League Baseball (and other professional sports)
- Emerging methods in:
  - *Data Science*
  - *Machine Learning*
  - *Artificial Intelligence*

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THE LATEST BIG FINDINGS

Using Analysis of Patterns in Time (APT)

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Based on *temporal maps* of *learning journeys* through the online Indiana University Plagiarism Tutorials and Tests (IPTAT):

- Students who try *any* part of IPTAT designed with First Principles of Instruction (FPI; Merrill, 2020) are 2 times more likely to achieve the learning goal than not.
- Students who try *all* parts of IPTAT designed with FPI are 4 times more likely to achieve the learning goal than not.
- Students who try *no* parts designed with FPI are 1.2 times more likely ***to fail to achieve*** the learning goal (using other parts not designed with FPI).
- These conclusions are based on *Analysis of Patterns in Time* of more than 131,000 learning journeys by adult students from 169 countries worldwide between Aug. 21 and Oct. 18, 2022.

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Enough for now? Learn more about *Analysis of Patterns in Time* at your own pace

- On the Web you can go to mapsat.iu.edu for access to
  - *Presentation slides for professional conferences*
  - *Screencasts of those slide presentations (with voice over)*
  - *Published journal articles, book chapters, and new book*
  - *Demonstration videos of how to do APT with Google Analytics*

- Map & Analyze Patterns & Structures Across Time: MAPSAT

https://mapsat.iu.edu

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A QUICK FLYOVER: 50 YEARS OF MY RESEARCH IN 15 MINUTES

Today’s presentation is analogous to a jet flyover from New York to San Francisco.
More details are in the underlined Web links.

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Searching for an alternative research methodology

- In 1972 I began my learning analytics quest (50 years ago):
  - ***How can we make learning better?***
    - What research methods are needed to verify this empirically?
    - How can we verify dynamically what teachers and students do that leads to student learning achievement?
- Empirical studies using quantitative linear models (multiple regression analysis, ANOVA, ANCOVA) lacked specificity because of the state-trait approach to measurement and algebraic linear assumptions
- Empirical studies using qualitative methods (ethnography, episodic narrative) lacked generalizability because of small sample sizes and selection bias

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1976: I invented *Nonmetric Temporal Path Analysis (NTPA) as an alternative*

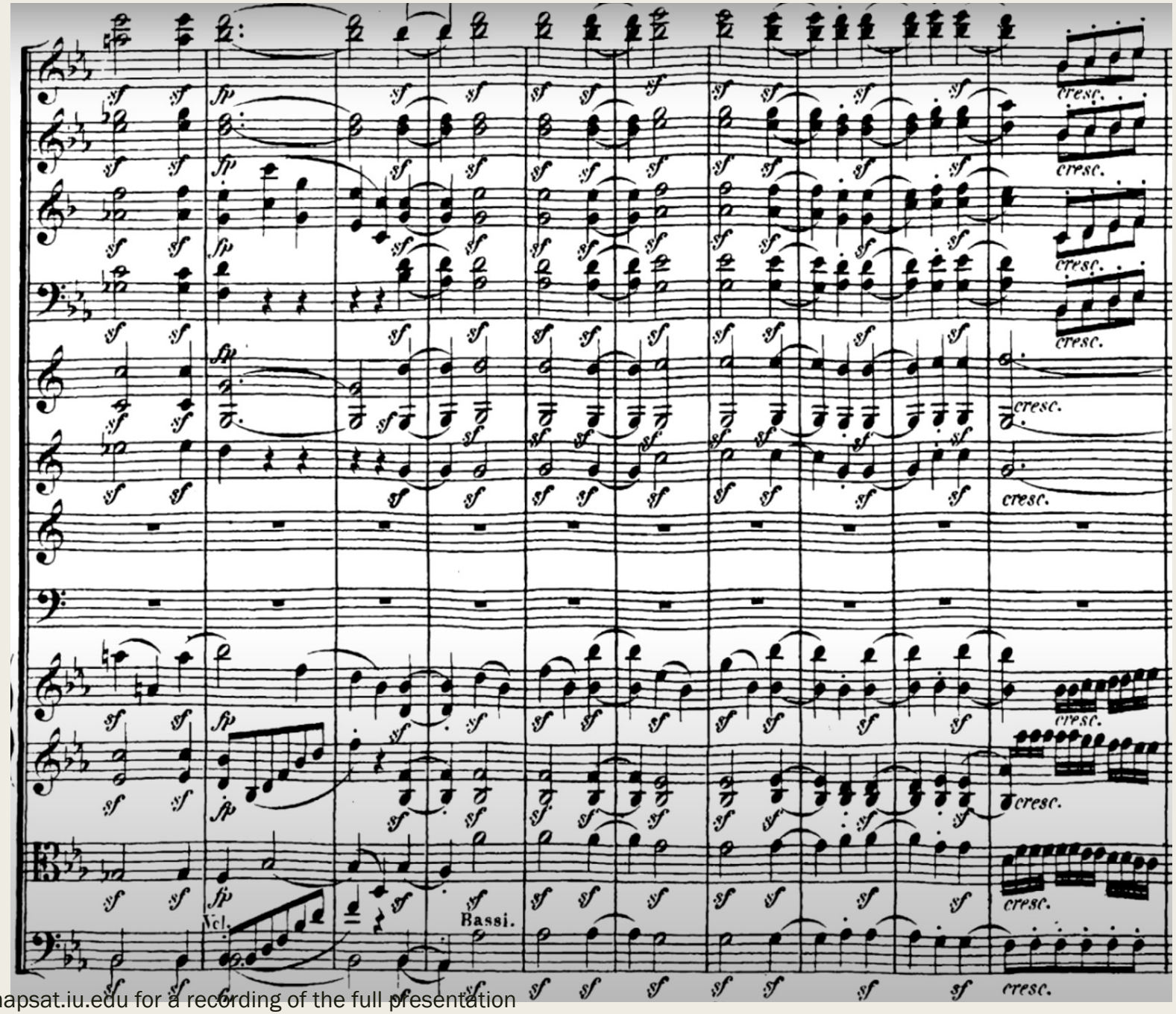
- The fundamental idea of a ***temporal map*** emerged
- We needed something analogous to orchestral scores and EKG's
  - *Parallel timelines*
  - *Ways to characterize change*

Temporal Map Example:

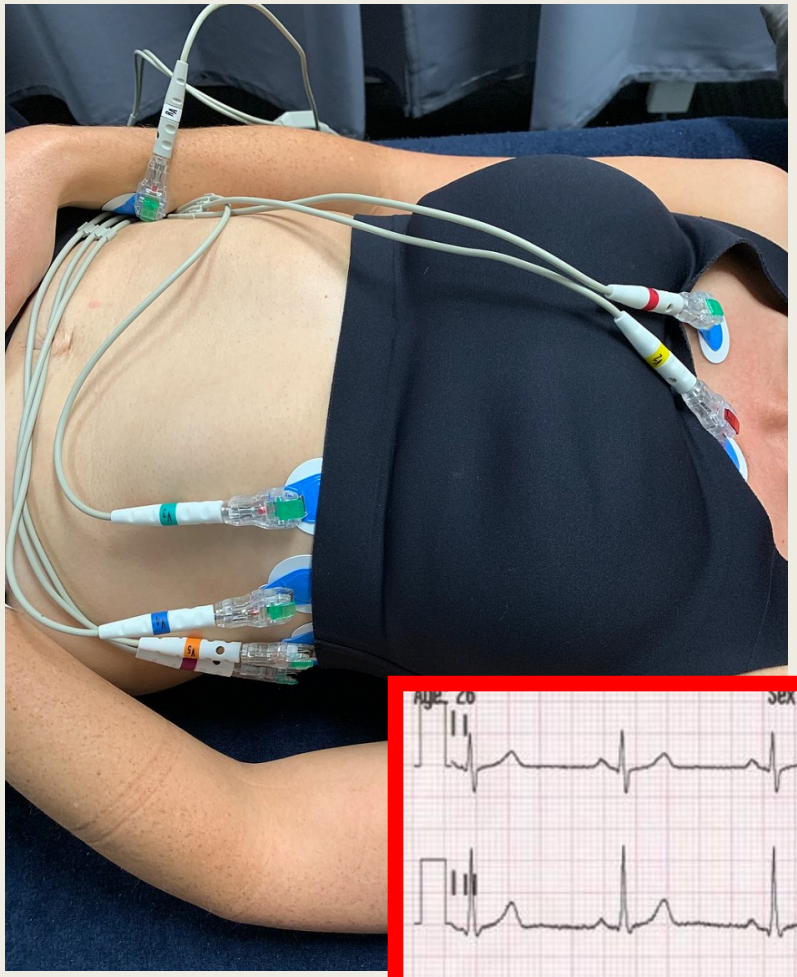
Orchestral score:

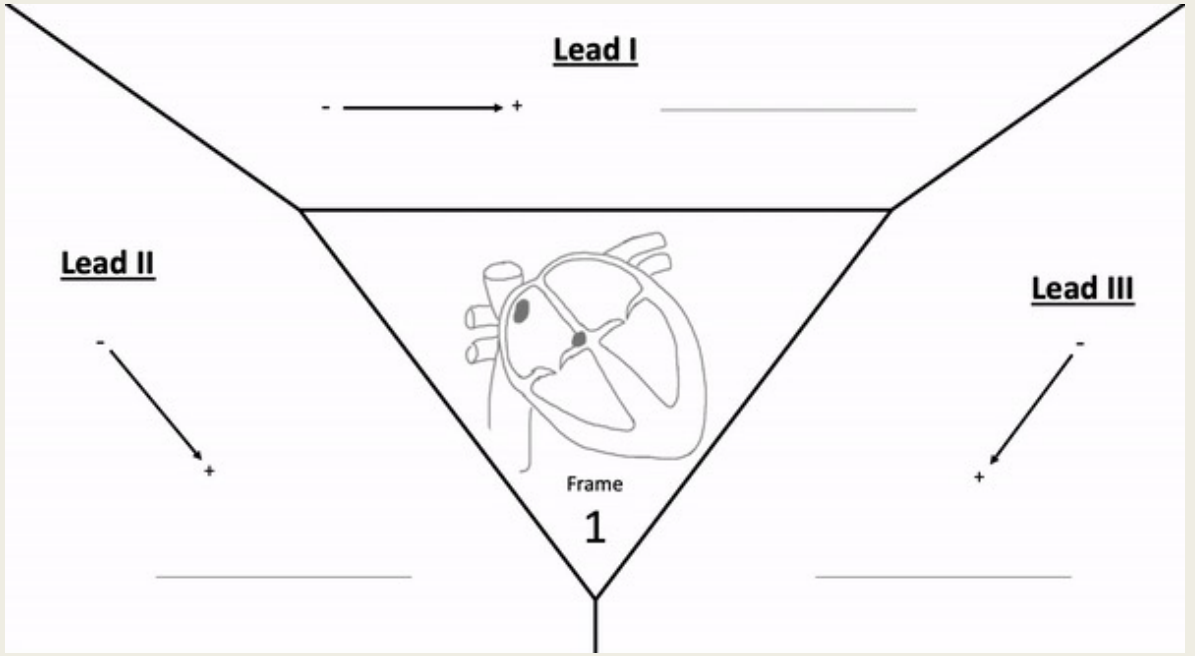
Excerpt from Beethoven's 3rd Symphony

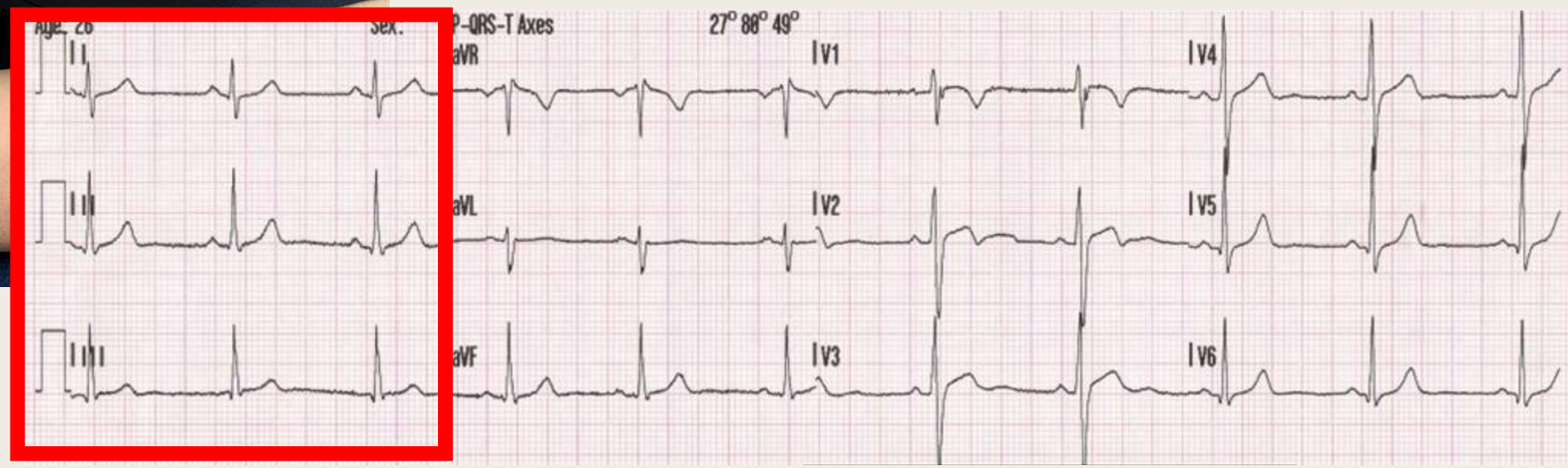
[source: YouTube]



Temporal Map Example: ECG: Electrocardiogram (heart) [source Wikipedia]







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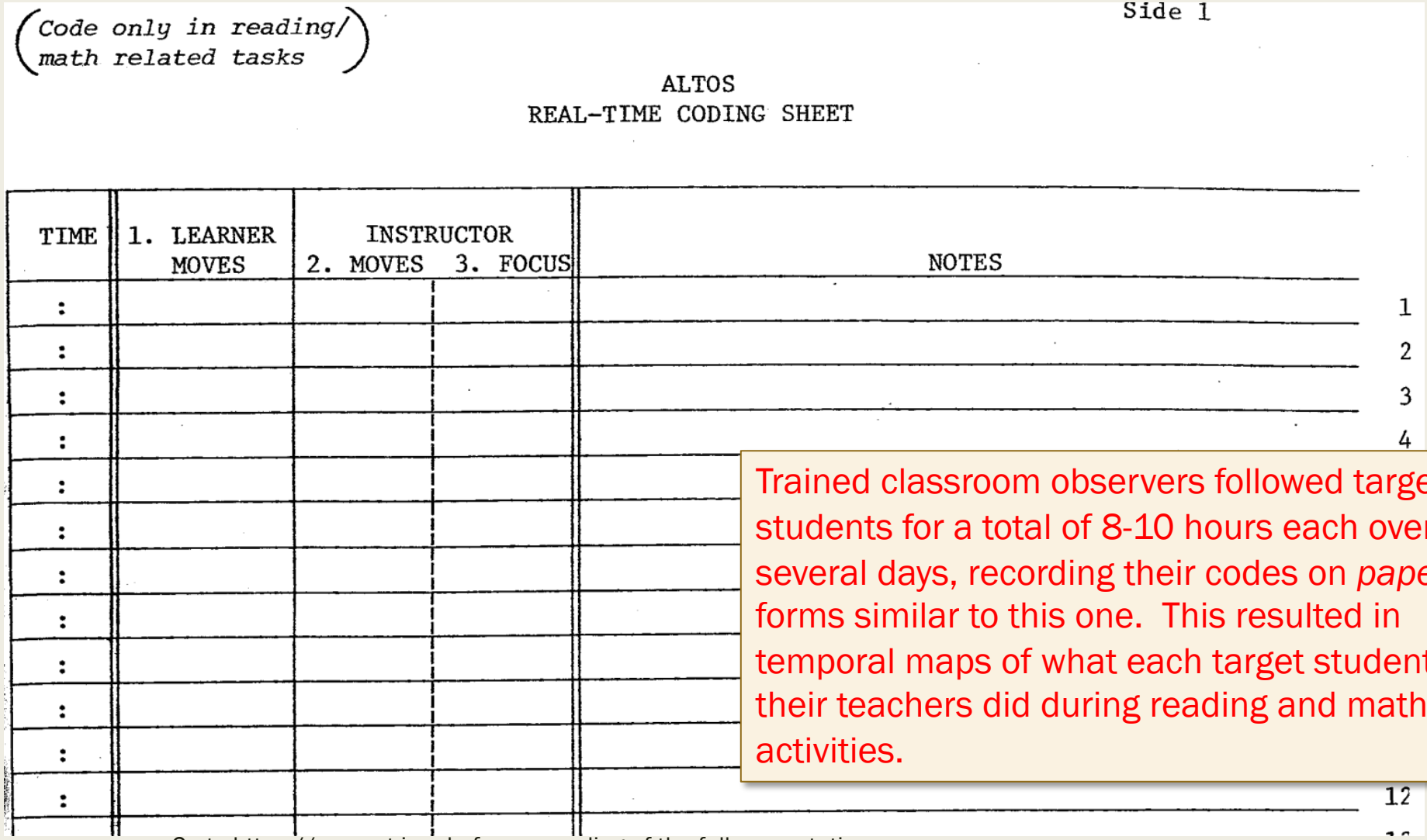
Temporal Map Example: ALTOS: Academic Learning Time Observation System [source: Frick & Rieth, 1981]



(Code only in reading/ math related tasks)

Side 1

ALTOS
REAL-TIME CODING SHEET

TIME	1. LEARNER MOVES	INSTRUCTOR 2. MOVES	3. FOCUS	NOTES	
:					1
:					2
:					3
:					4
:					
:					
:					
:					
:					
:					
:					12

Trained classroom observers followed target students for a total of 8-10 hours each over several days, recording their codes on *paper* forms similar to this one. This resulted in temporal maps of what each target student and their teachers did during reading and math activities.

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A Simple Temporal Map with 2 *Classifications*: Part of a Learning Journey

Key

Target Student Move
- Engaged (EN)
- Non-Engaged (NE)

Instructor Move
- Direct Instruction (DI)
- Non-Direct Instruction (ND)

Trained classroom observers tracked a target student and coded their moves and their instructor's moves at one-minute intervals

Joint Temporal Event (JTE)	Time (HH:MM)	Target Student Move	Instructor Move
1	10:15	NE	ND
2	10:16	NE	ND
3	10:17	EN	ND
4	10:18	EN	DI
5	10:19	EN	DI
6	10:20	NE	DI
7	10:21	EN	DI
8	10:22	NE	ND
9	10:23	NE	ND
10	10:24	NE	ND
11	10:25	EN	DI
12	10:26	EN	DI

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Temporal Map with NTPA Queries for part of a Learning Journey*

Joint Temporal Event (JTE)	Time (HH:MM)	Target Student Move	Instructor Move	Query 1 *p*(DI)	Query 2 *p*(EN)	Query 7 *p*(EN | DI)	Query 8 *p*(NE | DI)
1	10:15	NE	ND				
2	10:16	NE	ND				
3	10:17	EN	ND		1		
4	10:18	EN	DI	1	1	1	
5	10:19	EN	DI	1	1	1	
6	10:20	NE	DI	1			1
7	10:21	EN	DI	1	1	1	
8	10:22	NE	ND				
9	10:23	NE	ND				
10	10:24	NE	ND				
11	10:25	EN	DI	1	1	1	
12	10:26	EN	DI	1	1	1	

*a 1 signifies that the query is true for that JTE

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Temporal Map with further NTPA Queries for Learning Journey 1

Joint Temporal Event (JTE)	Time (HH:MM)	Target Student Move	Instructor Move	Query 1 $p(DI)$	Query 2 $P(EN)$	Query 3 $p(DI \cap EN)$	Query 4 $p(DI \cap NE)$	Query 5 $p(ND \cap EN)$	Query 6 $p(ND \cap NE)$	Query 7 $p(EN \mid DI)$	Query 8 $p(EN \mid ND)$
1	10:15	NE	ND						1		
2	10:16	NE	ND						1		
3	10:17	EN	ND		1			1			1
4	10:18	EN	DI	1	1	1				1	
5	10:19	EN	DI	1	1	1				1	
6	10:20	NE	DI	1			1				
7	10:21	EN	DI	1	1	1				1	
8	10:22	NE	ND						1		
9	10:23	NE	ND						1		
10	10:24	NE	ND						1		
11	10:25	EN	DI	1	1	1				1	
12	10:26	EN	DI	1	1	1				1	
(588 JTE's not shown here)											
600											
	Freq.			300	480	276	24	204	96	276	204
	Prob.			0.50	0.80	0.46	0.04	0.34	0.16	0.92	0.67

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1983: Frick dissertation findings: NTPA

Learning Journey	*p*(DI)	*p*(EN)	*p*(DI ∩ EN)	*p*(DI ∩ NE)	*p*(ND ∩ EN)	*p*(ND ∩ NE)	*p*(EN | DI)	*p*(EN | ND)
1	0.50	0.80	0.46	0.04	0.34	0.16	0.92	0.67
2	0.39	0.49	0.37	0.02	0.12	0.49	0.95	0.20
3	0.27	0.56	0.26	0.01	0.30	0.43	0.97	0.41
4	0.34	0.69	0.34	0.00	0.35	0.31	1.00	0.53
5	0.48	0.73	0.47	0.01	0.25	0.26	0.98	0.49
6	0.40	0.75	0.39				0.98	0.59
7 - 25	…	…	…				…	…
Mean (SD)	0.432 (0.144)	0.741 (0.101)	0.416 (0.139)	0.015 (0.010)	0.324 (0.114)	0.243 (0.104)	0.967 (0.029)	0.573 (0.142)

The likelihood of Student Engagement was 0.967 *when Direct Instruction was occurring.*

Key: DI = Direct Instruction; EN = Student Engagement;
NE = Student Non-Engagement; ND = Non-Direct Instruction

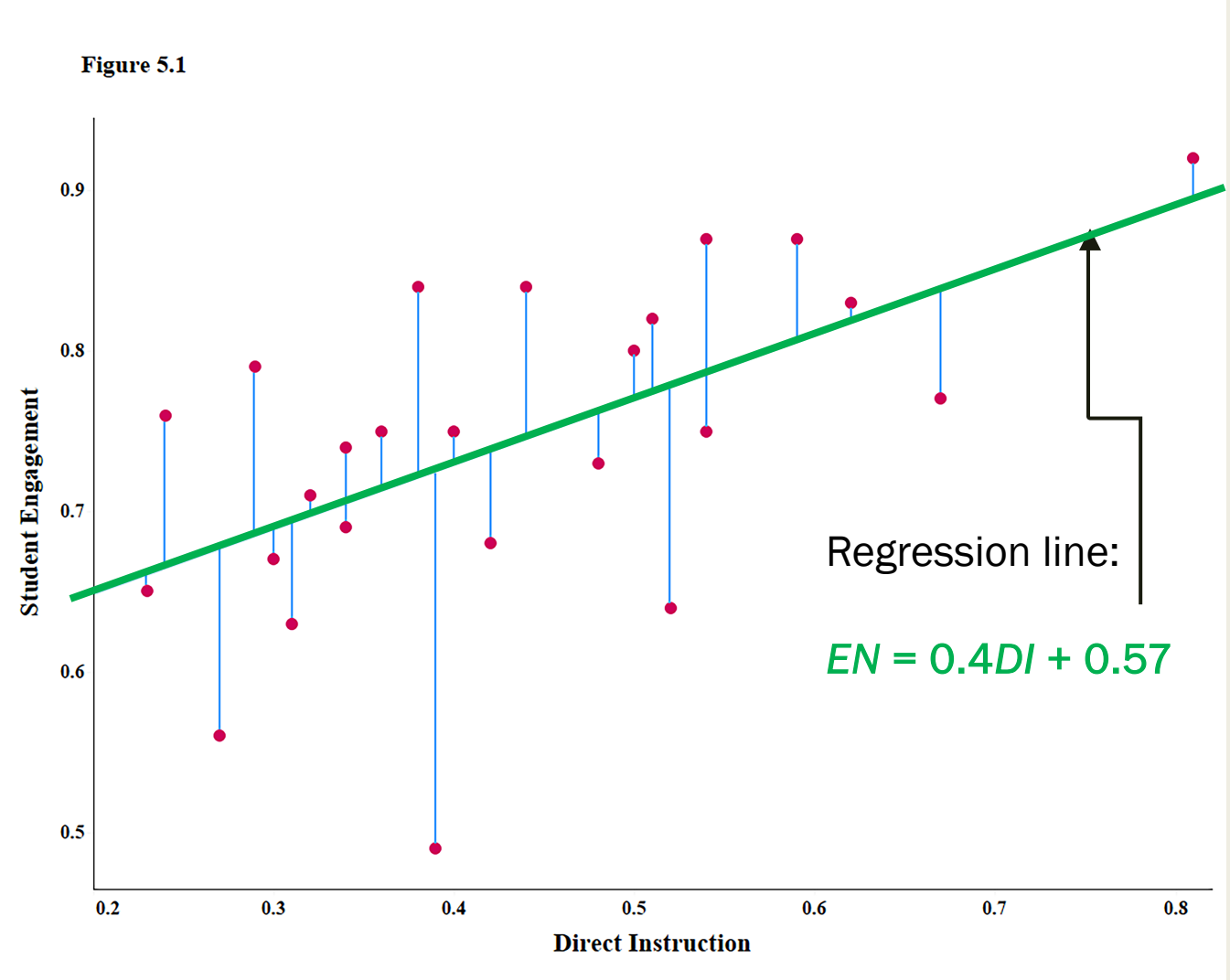
1983: Linear models scatterplot [Frick]

Pearson correlation

$r = 0.57$
$r^2 = 0.33$

NTPA probabilities

$p(EN|DI) = 0.97$
$p(EN|ND) = 0.57$
$p(NE|DI) = 0.03$
$p(NE|ND) = 0.43$



Key: DI = Direct Instruction; EN = Student Engagement;
NE = Student Non-Engagement; ND = Non-Direct Instruction

1983: Conclusion from *same classroom observations*

- **NTPA approach**
  - *When direct instruction is occurring, mildly handicapped students in elementary schools are engaged about 97 % of the time.*
  - *When direct instruction is not occurring, those students are engaged about 57 percent of the time. Students are about 13 times more likely NOT to be engaged in academic tasks when NO direct instruction is occurring.*
- **Linear models approach**
  - *The amount of time spent in direct instruction is correlated moderately and positively with the amount of student engagement time ($r = 0.57$)*
  - *33 % of the variance in student engagement time is predicted by the amount of direct instruction time; 67 % of the variance in student engagement time is NOT predicted by the amount of direct instruction ($r^2 = 0.57^2 = 0.33$; $1 - 0.33 = 0.67$)*

1983: Why the difference in conclusions from *same classroom observations?*

- NTPA approach *measures the relations*

  whereas

- Linear models approach *relates the measures*

- This is not a play on words, but a profound difference in approach to characterizing relations.

1990:

NTPA name changed to:

Analysis of Patterns in Time
(APT)

Method remained the same--only the name changed

American Educational Research Journal
Spring 1990, Vol. 27, No. 1, pp. 180–204

Analysis of Patterns in Time: A Method of Recording and Quantifying Temporal Relations in Education

Theodore W. Frick
Indiana University

Analysis of patterns in time (APT) is a method for gathering information about observable phenomena such that probabilities of temporal patterns of events can be estimated empirically. If appropriate sampling strategies are employed, temporal patterns can be predicted from APT results. As an example of the fruitfulness of APT, it was discovered in a classroom observational study that elementary students were on task 97% of the time if some form of direct instruction was occurring also, whereas they were on task only 57% of the time during nondirect instruction. As a second example, APT results were used as a rule base for an expert system in adaptive computer-based testing. When two different computer tests were studied, average samples of 9 and 13 test items were required to make mastery and nonmastery decisions when items were selected at random. These decisions were, respectively, 94% and 98% accurate compared to those reached from two much larger test item pools. Finally, APT is compared to the linear models approach and event history analysis. The major difference is that in APT there is no mathematical model assumed to characterize relations among variables. In APT the model is the temporal pattern being investigated.

What is Analysis of Patterns in Time (APT)?

- APT is a research methodology invented by Frick in 1970s
- APT is an alternative to the linear models approach (LMA—e.g., multiple regression, ANOVA): In the 1970s
  - *LMA was the prevalent quantitative approach to educational research*
  - *Qualitative methods were rarely used in educational research*
- APT draws from general systems theory, information theory, set theory, probability theory, and Bayesian reasoning
- ***Temporal maps*** are created as the main source of data for APT
- APT queries are then used to segment temporal maps for matching conditions, and for counting occurrences of temporal patterns
- APT queries result in probabilistic measures of temporal patterns (likelihoods, odds, cumulative time)

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Skipping a lot that happened with *APT* between 1990 and 2016

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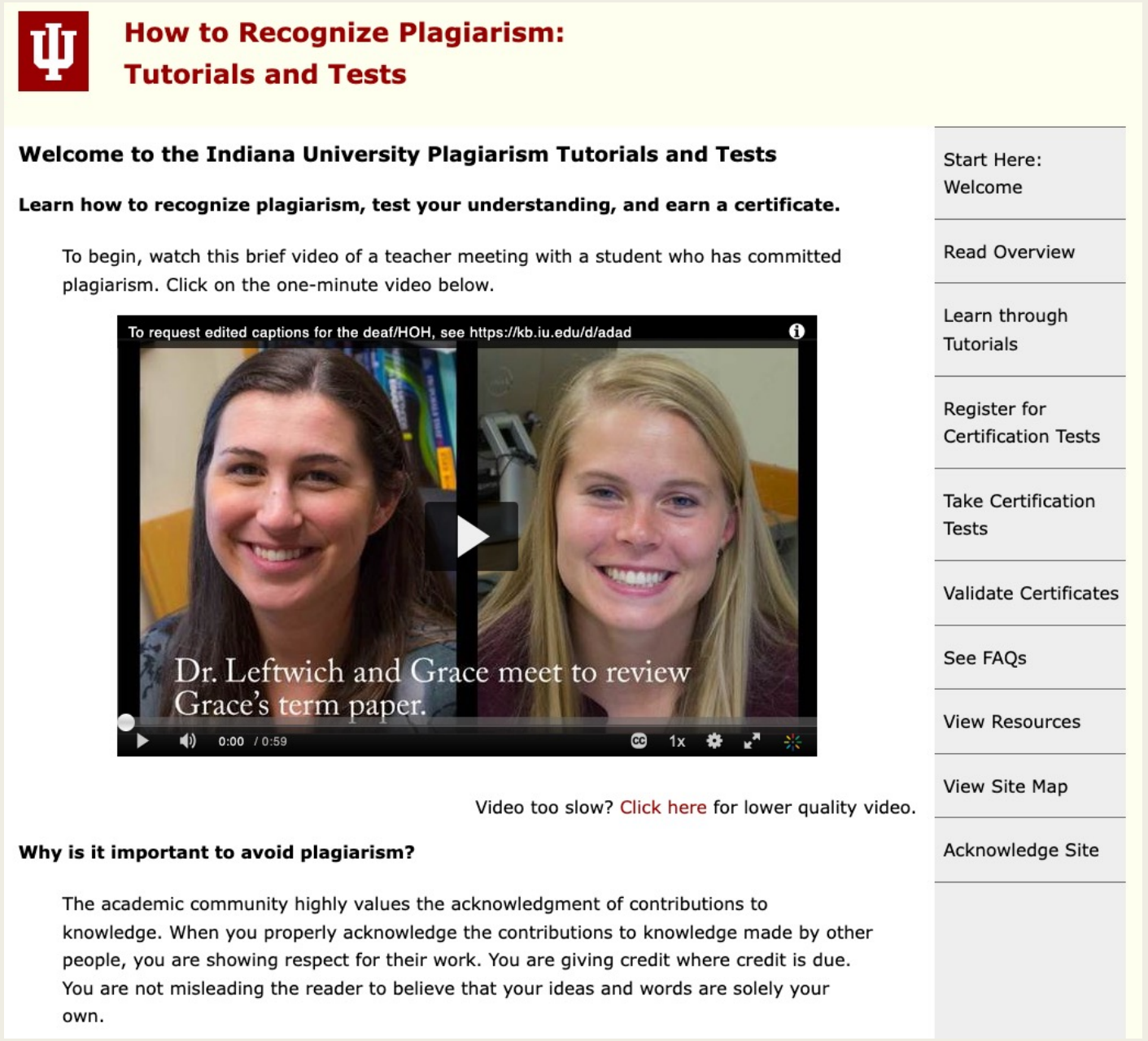
2016:

Redesign of Indiana University Plagiarism Tutorials and Tests (IPTAT) using First Principles of Instruction

[Initial design was in 2002]



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First Principles of Instruction (FPI) used to redesign IPTAT: [Source: Merrill, 2020]

1. ***Authentic problems or tasks*** for students to do, arranged from simple to complex (e.g., https://plagiarism.iu.edu/tutorials/index.html);
2. ***Activation*** of student learning by helping students connect new learning with what they already know or believe (e.g., https://plagiarism.iu.edu/tutorials/task1/activation.html);
3. ***Demonstration*** of what is to be learned, by showing a variety of examples (e.g., https://plagiarism.iu.edu/tutorials/task1/demonstration.html);
4. ***Application*** of what is being learned, so students can try themselves and feedback is provided (e.g., https://plagiarism.iu.edu/practiceTest.php?task=1&item=1); and
5. ***Integration*** of what has been learned into students' own lives (e.g., https://plagiarism.iu.edu/tutorials/task1/integration.html).

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From 2016 through 2020, Google Analytics was creating millions of APT temporal maps on IPTAT usage, but we did not know we could do APT queries with Google Analytics.

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Melinda's Learning Journey

Temporal Map

Part of Google Analytics 'session' on Sunday, October 4, 2020.

Melinda had 2 GA sessions, totaling 148 minutes in duration, separated by a 52-min. break between sessions.

Time	Web Page HTML Title	Web Page URL at https://plagiarism.iu.edu
5:53 p.m.	Certification Tests	/certificationTests/index.html
5:54 p.m.	Welcome	/index.html
5:54 p.m.	Certification Tests	/certificationTests/index.html
6:01 p.m.	Welcome	/index.html
6:05 p.m.	Organization of Instruction	/organization.html
6:06 p.m.	How to Navigate	/navigation.html
6:06 p.m.	Overview	/overview/index.html
6:07 p.m.	What you should do	/overview/shouldDo.html
6:08 p.m.	But I won't get caught	/overview/easyDetection.html
6:10 p.m.	R U a dupe?	/overview/RUAdupe.html
6:14 p.m.	The Slippery Slope with Symbolic Signs	/overview/signs.html
6:29 p.m.	Cases of Plagiarism	/overview/cases.html
6:33 p.m.	Tutorials and Practice Tests	/tutorials/index.html
6:33 p.m.	Task 1 Overview	/tutorials/task1/index.html
6:37 p.m.	A Video Case	/tutorials/task1/activation.html
6:44 p.m.	Demonstration	/tutorials/task1/demonstration.html
6:47 p.m.	Demonstration Continued	/tutorials/task1/demonstration2.html
6:50 p.m.	Practice with One Item at a Time	/practiceTest.php?task=1&item=1
6:51 p.m.	Practice Question Result and Feedback	/practiceTestResults.php
6:51 p.m.	Practice with One Item at a Time	/practiceTest.php?task=1&item=2
6:52 p.m.	Practice Question Result and Feedback	/practiceTestResults.php
6:52 p.m.	Practice with One Item at a Time	/practiceTest.php?task=1&item=3
6:52 p.m.	Practice Question Result and Feedback	/practiceTestResults.php
6:53 p.m.	Practice with One Item at a Time	/practiceTest.php?task=1&item=4
6:53 p.m.	Practice Question Result and Feedback	/practiceTestResults.php
6:53 p.m.	Task 1 Integration	/tutorials/task1/integration.html
ETC.		

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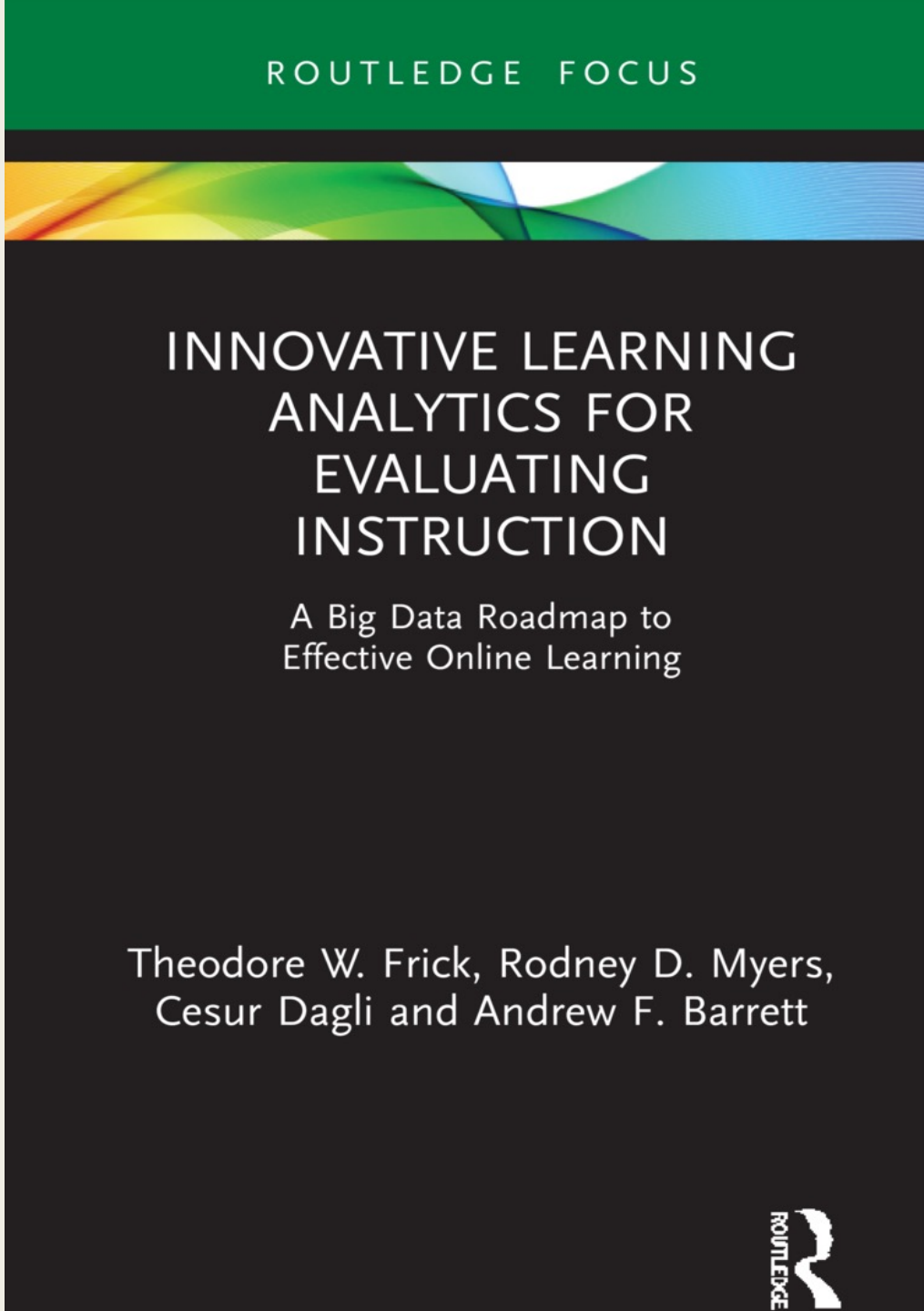
New book: 2022

- Google Analytics tracked student use of IPTAT website for 2 years, 2019-20
  - *Approximately 936,000 learning journeys, students from 222 countries and territories worldwide*
  - *About 1.9M temporal maps, 36M pageviews*
- We discovered in 2020 that Google's Universal Analytics (UA) could be leveraged to do Analysis of Patterns in Time (APT) when coupled with Excel spreadsheets
- Main APT finding: Successful students viewed 3 to 4 times as many unique Web pages designed with First Principles of Instruction as did unsuccessful students



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Latest APT Results from 131,083 Learning Journeys Using Google Analytics 4 (Aug. 21 – Oct. 18, 2022)

Learning Strategy	Non-Achiever	Achiever	Total	Likelihood of Passing	Likelihood of Failing	Odds P:F
Guessing (theoretical)	19,682	1	19,683	0.000	1.000	0.00
Minimalist (No FPI)	7,918	6,836	14,754	0.463	0.537	0.86
Traditionalist: Any FPI	16,532	34,551	51,083	0.676	0.324	2.09
Plagiarism Patterns Only	7,898	14,765	22,663	0.652	0.348	1.87
Practice Questions with Feedback	5,989	15,350	21,339	0.719	0.281	2.56
Maximalist (some of each FPI)	1,607	6,424	8,031	0.800	0.200	4.00
Achievers & Test Evals	40,838					
Non-Achievers & Test Evals	23,834					
Total Test Evals	64,672					
Active Users & No Test Evals	66,411					
Grand Total Learning Journeys	131,083					

Maximalists were 4 times more likely to pass a Certification Test. Maximalists had tried at least some of each part of IPTAT designed with First Principles of Instruction.

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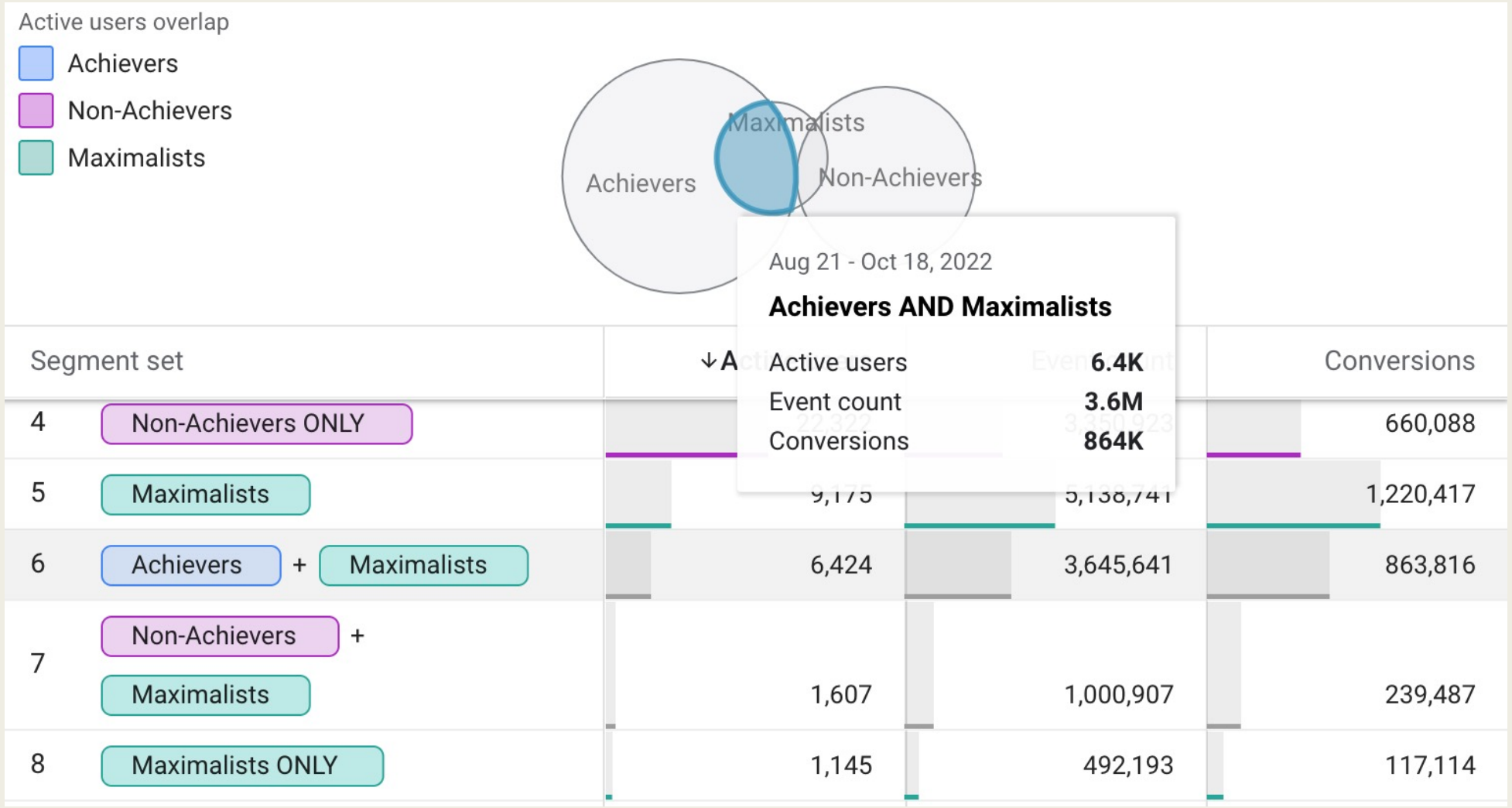
Doing Analysis of Patterns in Time with Google Analytics 4 (GA4) Segment Overlap



Segment set		↓Active users	Event count	Conversions
4	Non-Achievers ONLY	22,372	3,350,923	660,088
5	Maximalists	9,175	5,138,741	1,220,417
6	Achievers + Maximalists	6,424	3,645,641	863,816
7	Non-Achievers + Maximalists	1,607	1,000,907	239,487
8	Maximalists ONLY	1,145	492,193	117,114

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SUMMARY

After 50 years of research with Analysis of Patterns in Time

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Summary: Analysis of Patterns in Time

- APT is a fruitful methodology for investigating the instrumental value of instruction to promote student learning achievement.
- GA4 when supplemented with Excel can do some kinds of APT as envisioned originally by Frick (1983, 1990) and Myers and Frick (2015).
- GA4 is somewhat easier to use for doing APT when compared with Google's earlier Universal Analytics. In both cases, Excel is needed for further computations of likelihoods and Bayesian analysis.
- For more on APT and designing online instruction with First Principles of Instruction, see our new book: *Innovative Learning Analytics for Evaluating Instruction: A Big Data Roadmap for Effective Online Learning* (2022, Routledge Focus Series)

Go to https://mapsat.iu.edu for a recording of the full presentation

References

Frick, T. W. (1983). *Nonmetric temporal path analysis: An alternative to the linear models approach for verification of stochastic educational relations* [Unpublished doctoral dissertation]. Indiana University Graduate School. https://tedfrick.sitehost.iu.edu/ntpa/

Frick, T. W. (1990). Analysis of patterns in time (APT): A method of recording and quantifying temporal relations in education. *American Educational Research Journal, 27*(1), 180-204. https://tedfrick.sitehost.iu.edu/apt/aerj.pdf

Frick, T. W. & Dagli, C. (2016). MOOCs for research: The case of the Indiana University plagiarism tutorials and tests. *Technology, Knowledge and Learning*, *21*(2), 255-276. https://rdcu.be/mEvf

Frick, T. W., Myers, R. D., & Dagli, C. (2022). Analysis of Patterns in Time for Evaluating First Principles of Instruction (SharedIt): https://doi.org/10.1007/s11423-021-10077-6

Frick, T. W., Myers, R. D., Dagli, C., & Barrett, A. F. (2022). *Innovative learning analytics for evaluating instruction: A big data roadmap to effective online learning*. Routledge. https://doi.org/10.4324/9781003176343

Google Analytics (2005 - present). Wikipedia entry: https://en.wikipedia.org/wiki/Google_Analytics

Indiana University Plagiarism Tutorials and Tests (2002-present). How to recognize plagiarism. Retrieved from https://plagiarism.iu.edu

Merrill, M. D. (2020). *M. David Merrill's first principles of instruction*. Association for Educational Communications and Technology.

Myers, R. & Frick, T. W. (2015). Using pattern matching to assess gameplay. In C. S. Loh, Y. Sheng, & D. Ifenthaler (Eds.), *Serious games analytics: Methodologies for performance measurement, assessment, and improvement*, (Chapter 19, pp. 435-458). Springer. https://tedfrick.sitehost.iu.edu/apt/patternMatchingToAssessGameplay.pdf

Viewers of this presentation would also benefit from complementary presentations at AECT:

- Frick, T. (2022, Oct.). *MOOC Turns 20 Years Old: How to Recognize Plagiarism*. At the annual conference of the Association of Educational Communications and Technology, Las Vegas, NV.

  Thu, Oct 27, 2:10 to 2:25pm PDT (5:10 to 5:25pm EDT), Virtual, Online B

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Acknowledgements

- Recent contributors to research with Analysis of Patterns in Time
  - *Rodney Myers, Ph.D., Indiana University*
  - *Cesur Dagli, Ph.D., Virginia Tech University*

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Links for Using Google Analytics to do Analysis of Patterns in Time (APT)

Video demonstrations

https://plagiarism.iu.edu/apt/demo/index.html

For background on APT, see also

https://plagiarism.iu.edu/apt/index.html

Slides of this presentation (PDF)

https://plagiarism.iu.edu/apt/APT_FruitfulMethod.pdf

Link to recording of this presentation

https://mapsat.iu.edu