Virtual Presentation to International Lab:
Research on Learning Analytics and Instructional Design

Analysis of Patterns in Time: Innovative Learning Analytics with Google Analytics 4

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February 11, 2022

My Background

Professional Experience

1974 – 1983: Research Associate, Center for Innovation in Teaching the Handicapped, Indiana University Bloomington

1984 – 2012: Professor, Department of Instructional Systems Technology (IST)

1998 – 2005: Web Director, School of Education

2010 – 2012: Department Chair, IST

Currently

2013 – Present: Professor Emeritus, Department of Instructional Systems Technology, School of Education, Indiana University Bloomington

(see https://tedfrick.sitehost.iu.edu for links to publications, vita, etc.)

For me, it began about 50 years ago…

- **1972** Context
  - *Lack of empirical research showing clear relationships between classroom process variables (now called learning analytics) and student academic achievement*
  - *Do teachers make a difference? (follow-up to Coleman et al. (1966)* national study on equality of educational opportunity in U.S.)
  - *Dependability of behavioral measurements (Cronbach et al*., 1972): variability of classroom processes, teacher/student interaction; partitioning sources of error variance
- **Why lack of research findings?**
  - *Measurement error due to disagreement among classroom observers?* Possibly
  - *Linear models approach obfuscating temporal patterns?* Yes
  - *Wrong measurement paradigm?* Yes
- **Circa 1976 - 1983:** I invented Analysis of Patterns in Time (APT) as an alternative measurement approach
- **2022:** *Innovative Learning Analytics for Evaluating Instruction* (new book)

Summary of today's presentation

- I discovered in 2020 that Google Analytics has effectively implemented many ideas from Analysis of Patterns in Time (APT).
- GA tracking sessions can be treated as APT temporal maps.
- If used creatively, GA reporting tools can be used to count patterns needed for APT.
- Google Analytics can be leveraged to do APT when supplemented with spreadsheet calculations.

Overview of today's presentation

- Serendipitous discovery in Feb. 2020 that Google Analytics might be adapted to do some parts of Analysis of Patterns in Time (APT)
  - *APT invented in the 1970s*
  - *Google Analytics started in 2005 after purchase of two companies: Urchin (on Demand) and Adaptive Path (Measure Map)*
- Unplanned book emerged about this discovery during COVID pandemic (Frick et al., 2022)
- Fundamentals of APT: temporal maps and APT queries
- Illustration of how to do APT with Google Analytics 4

Not how we originally had planned it

- We did not plan for the Big Study to happen this way.
- After redesigning and implementing the Indiana University Plagiarism Tutorials and Tests (IPTAT), our original plan for APT Study 2 was outlined in Frick and Dagli (2016):

  > Behind the scenes, IPTAT software will create individual temporal maps that track each student's choices as he or she navigates and completes learning activities in the IPTAT, including that student's performance on a Certification Test. (p. 257)

- Unknown to us, Google had already developed tracking software that had been creating temporal maps needed for APT.
- Fortuitously, IPTAT designers had named web pages according to First Principles of Instruction that were used to design them—for our own benefit, not for Google Analytics.
- The main reason we implemented Google Analytics in 2016 was because university technology services stopped providing in-house web statistics.

Backstory: We got lucky—serendipity happened

- I was homebound during COVID emergence in late Feb. 2020. Doing routine check on use of the online Indiana University Plagiarism Tutorials and Tests (IPTAT)
- Using Google Analytics (GA) for generating reports on IPTAT usage—did not know at that time that GA 'sessions' were in effect temporal maps needed for APT
- Out of boredom and curiosity, was exploring 'admin' tools in GA
- Discovered an 'admin' tool for segmenting users according to matching conditions—this tool was buried in GA settings under 'Personal Tools & Assets' within 'Views'.
- Suddenly realized that segmenting of users could be combined with the GA Behavior analysis tool AND that further searches within reports for IPTAT filename matches could result in counts of temporal events needed for APT.
- This was NOT obvious. Probably not obvious to Google either. A lucky coincidence.
- Eureka! We have Big Data on years of IPTAT usage by millions of users. Google software engineers had already built a data collection platform and analysis tools that might be used for APT! Who knew? How far could we push GA to do APT?

What is Analysis of Patterns in Time (APT)?

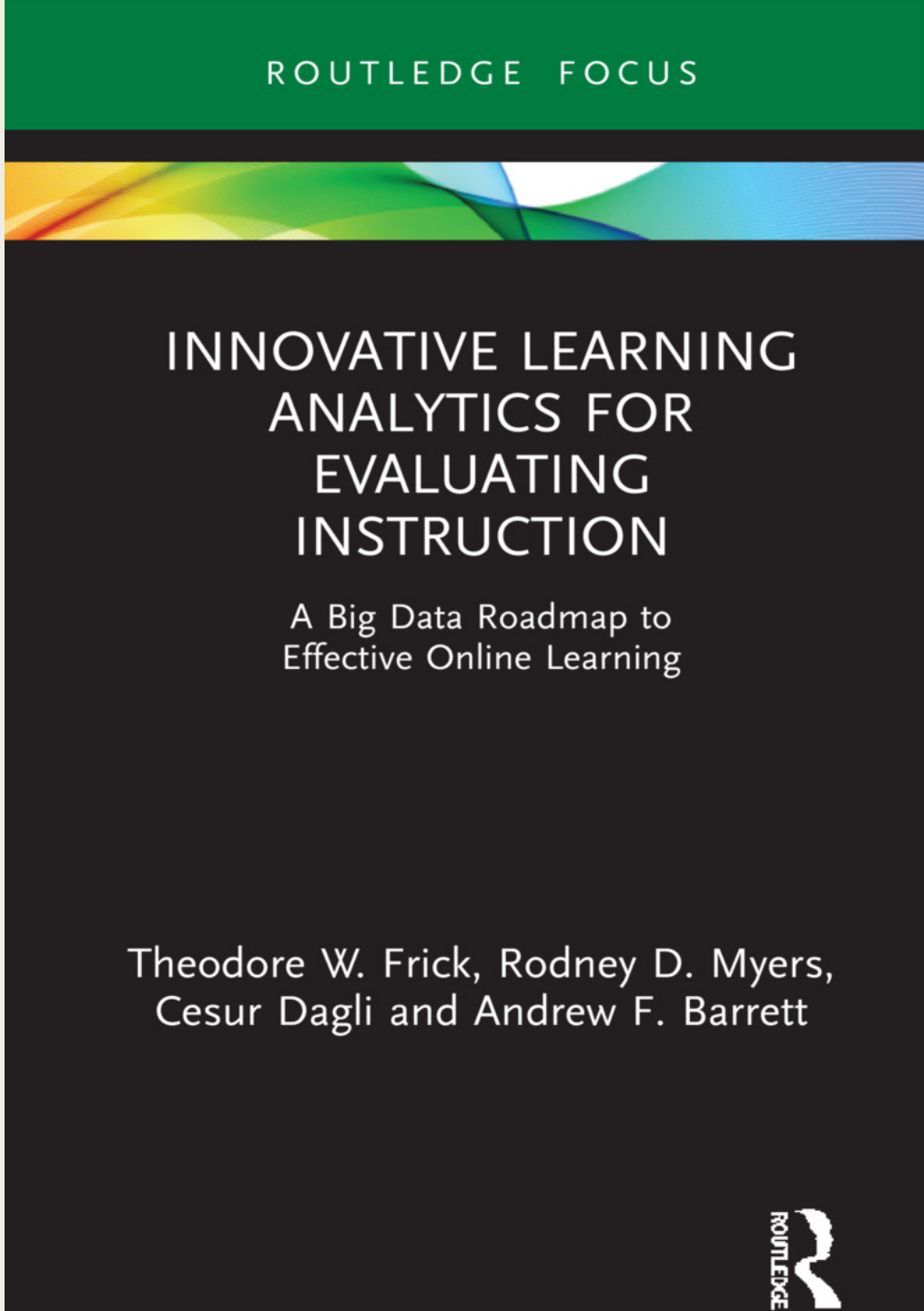
- APT is a research methodology invented by Frick in 1970s
- APT is an alternative to the linear models approach (LMA—e.g., multiple regression, ANOVA): In the 1970s
  - *LMA was the prevalent quantitative approach to educational research*
  - *Qualitative methods were rarely used in educational research*
- 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)

New Book Rapidly Emerged in 2020

- I was at risk for COVID due to age--concerned that this discovery might get lost if I got sick or died from COVID
- In 2016, when we incorporated Google Analytics in IPTAT, we did not know GA could be used for APT
- Started writing extensive notes about this discovery and how to adapt GA to do APT, when coupled with Excel spreadsheets
- Shared ideas with colleagues who had previously worked on research teams in IST at IU using APT methods in their research:
  - *Rod Myers*
  - *Cesur Dagli*
  - *Andrew Barrett*
  - *and a few other close colleagues*

New Book: Big Study over 2 years, 2019-2020

- Approximately 936,000 learning journeys, students from 222 countries and territories worldwide
- About 1.9M temporal maps, 36M pageviews
- Google Analytics for tracking student use of IPTAT website
- Discovered in 2020 that 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.



GOOGLE ANALYTICS 4

Introduced in Mid-October, 2020

Main Research Question: Follow-up Study to the Big Study*

Can Google Analytics 4 (GA4) be used to do Analysis of Patterns in Time (APT)? If so, how?

**Note: We used GA Universal Analytics (UA) in the Big Study, 2019 - 2020*

In the Big Study we investigated IPTAT learning journeys with APT

- Indiana University Plagiarism Tutorials and Tests (IPTAT) online: https://plagiarism.iu.edu
- Redesigned IPTAT in 2015 using First Principles of Instruction (FPI)
- Evaluated the effectiveness of FPI

First Principles of Instruction (FPI): Merrill, 2002, 2013, 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).

Basic Level: Recognize the basic difference between:

- *avoiding* plagiarism, and
- *committing* plagiarism.

Novice Level: When *one source is used*, recognize a proper quotation from an improper quotation:

- a *proper quotation* of someone else's words, and
- provision of the appropriate citation and reference.

Intermediate Level: When *one source is used*, recognize a proper paraphrase from an improper paraphrase:

- a *proper paraphrase* of someone else's words, and
- provision of the appropriate citation and reference.

Advanced Level: When *one source is used*, recognize various combinations of:

- *proper/improper paraphrasing*, and
- *proper/improper quotations.*

Expert Level: Put it all together. When *two or more sources are used*, recognize various combinations of:

- *proper/improper paraphrasing*, and
- *proper/improper quotations.*

IPTAT TUTORIALS DESIGN IN 2015

Apply First Principle #1: sequence ***authentic tasks*** from simple to complex

IPTAT Design Example

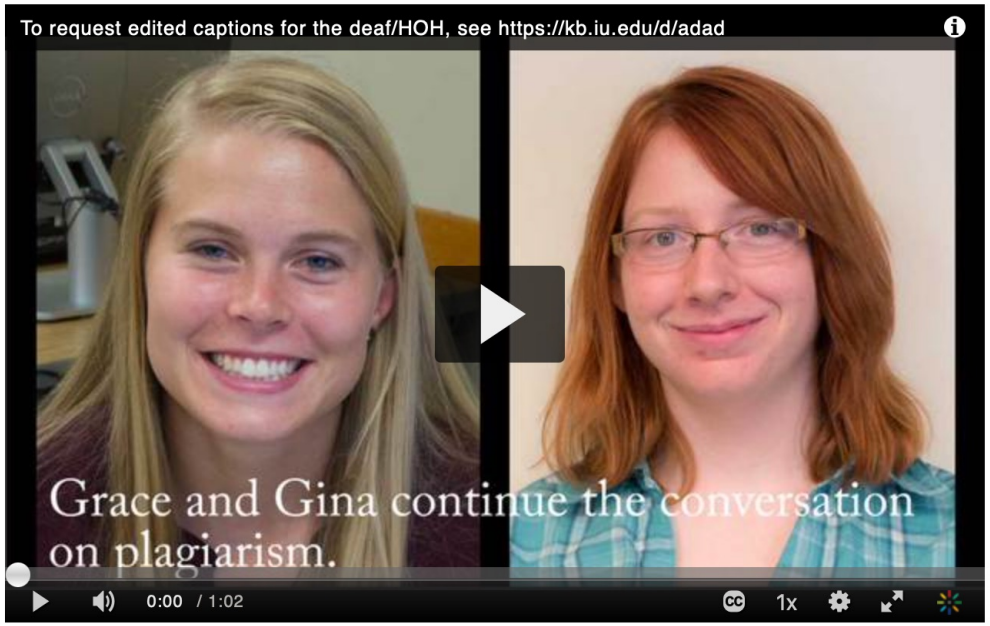
Apply the FPI Activation principle

How to Recognize Plagiarism: Tutorials and Tests

Instruction: *Novice Level*

A Video Case

Grace and Gina discuss how to properly quote someone else's words and to cite the author(s). Click the one-minute video below to view this case.



Task Level	Level Name	First Principle	Pages/ Instances	Page URLs at https://plagiarism.iu.edu
1	Basic	Activation	1/1	/tutorials/task1/activation.html
		Demonstration	2/4	/tutorials/task1/demonstration.html /tutorials/task1/demonstration2.html
		Application	4/4	/practiceTest.php?task=1&item=1 … 4
		Integration	1/1	/tutorials/task1/integration.html
		Practice Test	1/4	/tutorials/task1/masteryTest.php
2	Novice	Activation	1/1	/tutorials/task2/activation.html
		Demonstration	1/2	/tutorials/task2/demonstration.html
		Application	4/4	/practiceTest.php?task=2&item=1 … 4
		Integration	1/1	/tutorials/task2/integration.html
		Practice Test	1/4	/tutorials /task2/masteryTest.php
3	Intermediate	Activation	1/1	/tutorials/task3/activation.html
		Demonstration	1/2	/tutorials/task3/demonstration.html
		Application	4/4	/practiceTest.php?task=3&item=1 … 4
		Integration	1/1	/tutorials/task3/integration.html
		Practice Test	1/4	/tutorials /task3/masteryTest.php
4	Advanced	Activation	2/2	/tutorials/task4/activation.html /tutorials/task4/activation2.html
		Demonstration	1/2	/tutorials/task4/demonstration.html
		Application	8/8	/practiceTest.php?task=4&item=1 … 8
		Integration	1/1	/tutorials/task4/integration.html
		Practice Test	1/8	/tutorials /task4/masteryTest.php
5	Expert	Activation	3/3	/tutorials/task5/activation.html /tutorials/task5/activation2.html /tutorials/task5/activation3.html
		Demonstration	1/2	/tutorials/task5/demonstration.html
		Application	10/10	/practiceTest.php?task=5&item=1 … 10
		Integration	1/1	/tutorials/task5/integration.html
		Practice Test	1/10	/tutorials /task5/masteryTest.php
All	Patterns	Demonstration	19/18	/plagiarismPatterns/…

STRUCTURE: IPTAT TUTORIALS DESIGN IN 2015

To do APT, we need to create temporal maps of coded event occurrences

- Each *temporal map* is basically a spreadsheet or table for characterizing a unique case or situation
- Each map row consists of a date/time stamp and *coding* of one or more event occurrences at that time
  - *Each classification consists of two or more mutually exclusive categories which are used to code events*
  - *Multiple classifications can be used, one for each column*
- Each new row represents the sequential order through time in which those coded events occurred

Sam’s Case

An Example of Sam’s Learning Journey through IPTAT on Tues., Oct. 6, 2020

How to Recognize Plagiarism: Tutorials and Tests

Welcome to the Indiana University Plagiarism Tutorials and Tests

Learn how to recognize plagiarism, test your understanding, and earn a certificate.

To begin, watch this brief video of a teacher meeting with a student who has committed plagiarism. Click on the one-minute video below.

Video too slow? Click here for lower quality video.

Why is it important to avoid plagiarism?

The academic community highly values the acknowledgment of contributions to knowledge. When you properly acknowledge the contributions to knowledge made by other people, you are showing respect for their work. You are giving credit where credit is due. You are not misleading the reader to believe that your ideas and words are solely your own.

APT
Temporal Map

Sam's Learning Journey

User View	Time	#	Web Page URL at https://plagiarism.iu.edu	Page: User Action
	06:21:32 a.m.	1	/index.html	IPTAT Welcome: selects "Take Certification Tests".
	06:22:28 a.m.	2	/certificationTests/index.html	Take Certification Test: selects "Undergraduate and Advance High School Student".
	06:22:35 a.m.	3	/mainLogin.php	Login for Certification Test: selects link to register.
	06:22:37 a.m.	4	/register.html	Register for Certification Test: selects link "I am an undergraduate …".
	06:22:48 a.m.	5	/mainLogin.php?action=register&testLevel=UG	Register as an Undergraduate … : completes form and submits it.
	06:25:41 a.m.	6	/mainLogin.php?action=registration&testLevel=UG	IPTAT Instructions: Go to your e-mail now.
	No Google Analytics event stored	--	E-mail app, not IPTAT	User reads e-mail and selects link to confirm registration.
	06:27:47 a.m.	7	/mainLogin.php?action=activate&testLevel=UG	Registration is activated: logs in to take UG test.
	06:27:58 a.m.	8	/plagiarismTestUG.php?testLevel=UG (One of trillions of randomized Certification Tests)	Takes test and submits it for evaluation.
	06:33:18 a.m.	9	/evaluateAnswersTestUG.php	UG Test Evaluation: user does not pass, clicks on first link for type of plagiarism.

Temporal Map cont'd:

Sam's Learning Journey

	06:34:56 a.m.	10	/plagiarismPatterns /patternCunningCoverUp.html	Plagiarism Pattern: user missed a Cunning Cover-Up question. Selects back button on browser.
	06:35:22 a.m.	11	/evaluateAnswersTestUG.php	Returns to UG Test Evaluation: clicks on next link for type of plagiarism.
	06:35:25 a.m.	12	/plagiarismPatterns /patternDeceptiveDupe.html	Plagiarism Pattern: user missed a Deceptive Dupe question. Selects back button on browser.
	06:37:01 a.m.	13	/evaluateAnswersTestUG.php	Returns to UG Test Evaluation: clicks on button "Learn how to recognize plagiarism".
	06:37:21 a.m.	14	/index.html	Returns to Welcome Page: user decides to quit for now, and plans to come back later. Closes browser window.

Melinda's Case

Temporal Map

Sunday, October 4, 2020

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

WE CAN “TEACH” GA4 TO CREATE CODES FOR EVENTS

In our case, we want to code webpages according to the First Principle of Instruction Used to design that page.

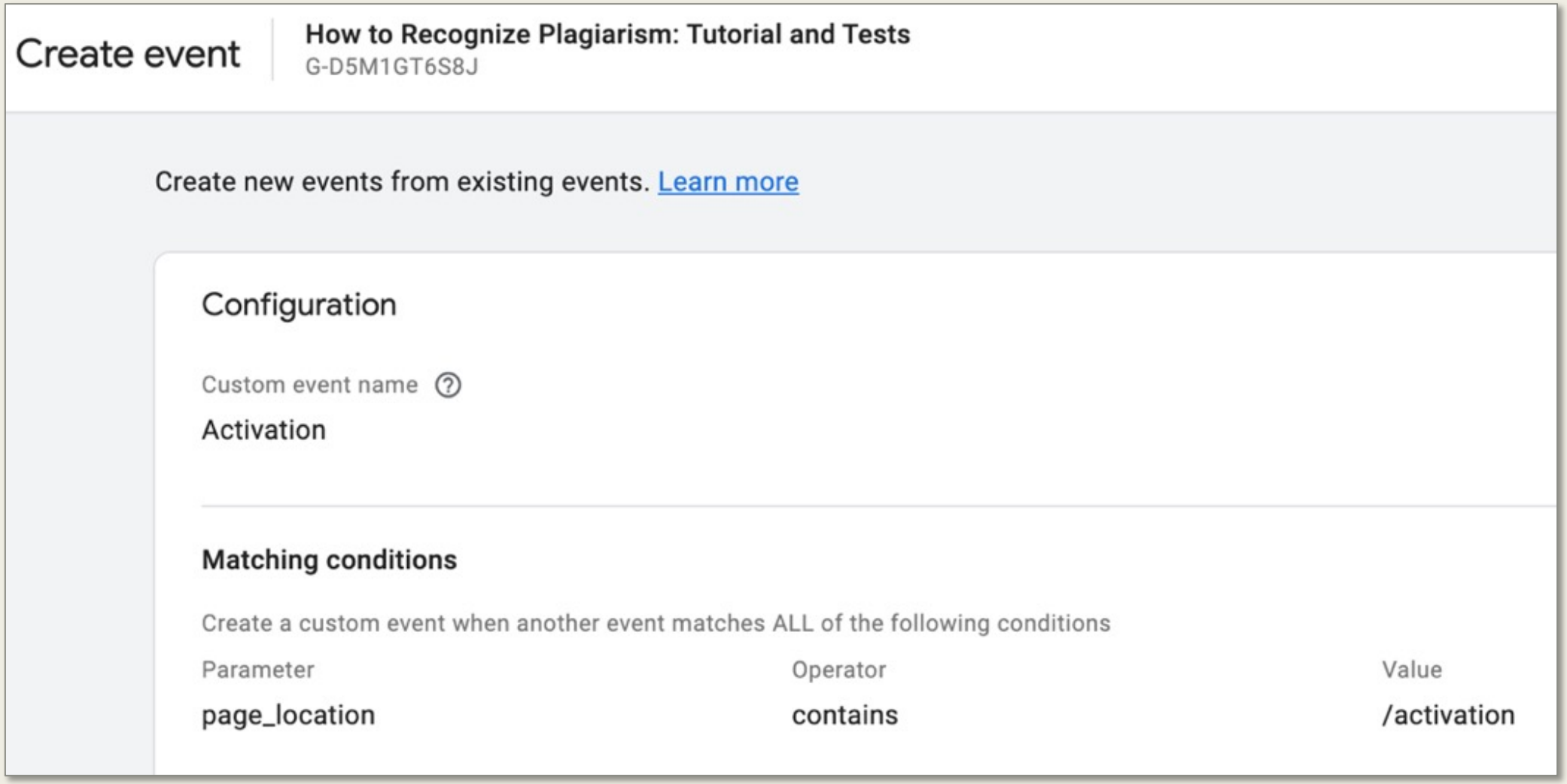
You can view demonstration videos on the Web and read the research publication

Click here for list of 8 demonstration videos
(approximately 85 minutes in total)

This *ETR&D* publication explains our analysis in greater detail:

Analysis of Patterns in Time for
Evaluating First Principles of Instruction
(Frick, Myers & Dagli, 2022)

Create New GA4 Conversion Events, e.g., for FPI Activation



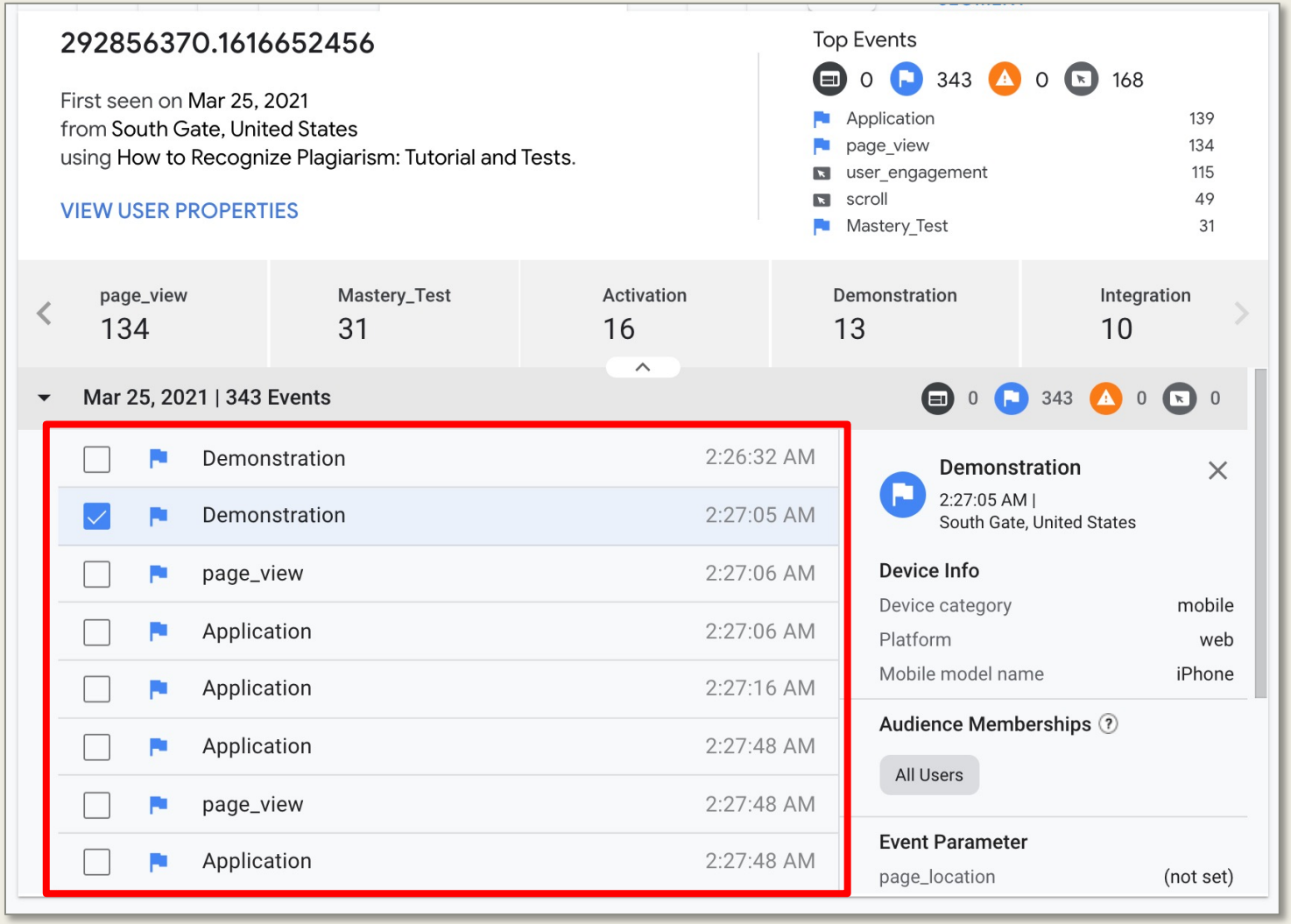
Event Name	Marked as conversion
Activation	TRUE
Application	TRUE
click	FALSE
Demonstration	TRUE
file_download	FALSE
first_visit	FALSE
Integration	TRUE
Mastery_Test	TRUE
page_view	TRUE
Pass_GR_Test	TRUE
Pass_UG_Test	TRUE
Plagiarism_Patterns	TRUE
Plagiarism_Test	TRUE
scroll	FALSE
session_start	FALSE
Test_Feedback	TRUE

GA4 EVENTS

CREATE NEW CONVERSIONS (GA4 GOALS)

Note: new conversion event names begin in uppercase; events that GA4 tracks by default are lowercase names.

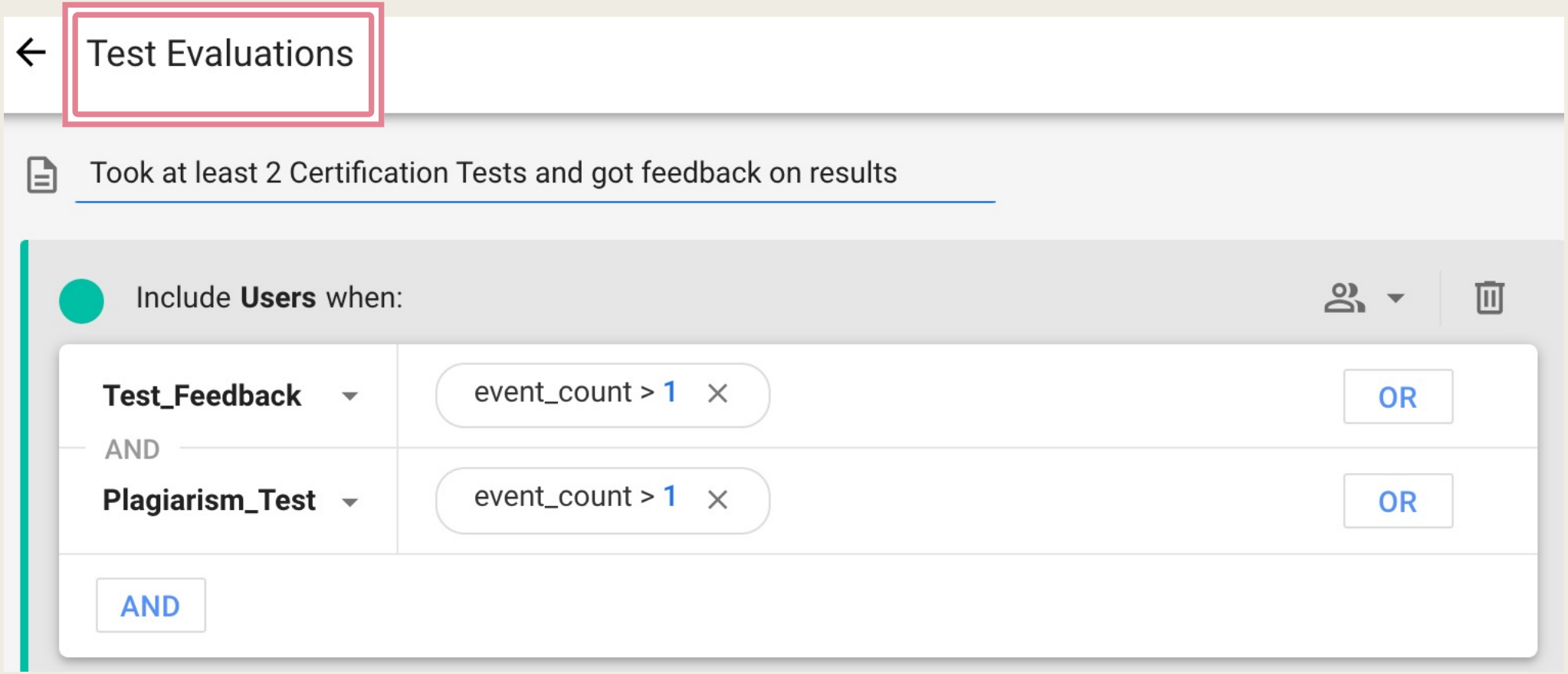
GA4 Explorer: APT Temporal Map of a *Student Learning Journey*



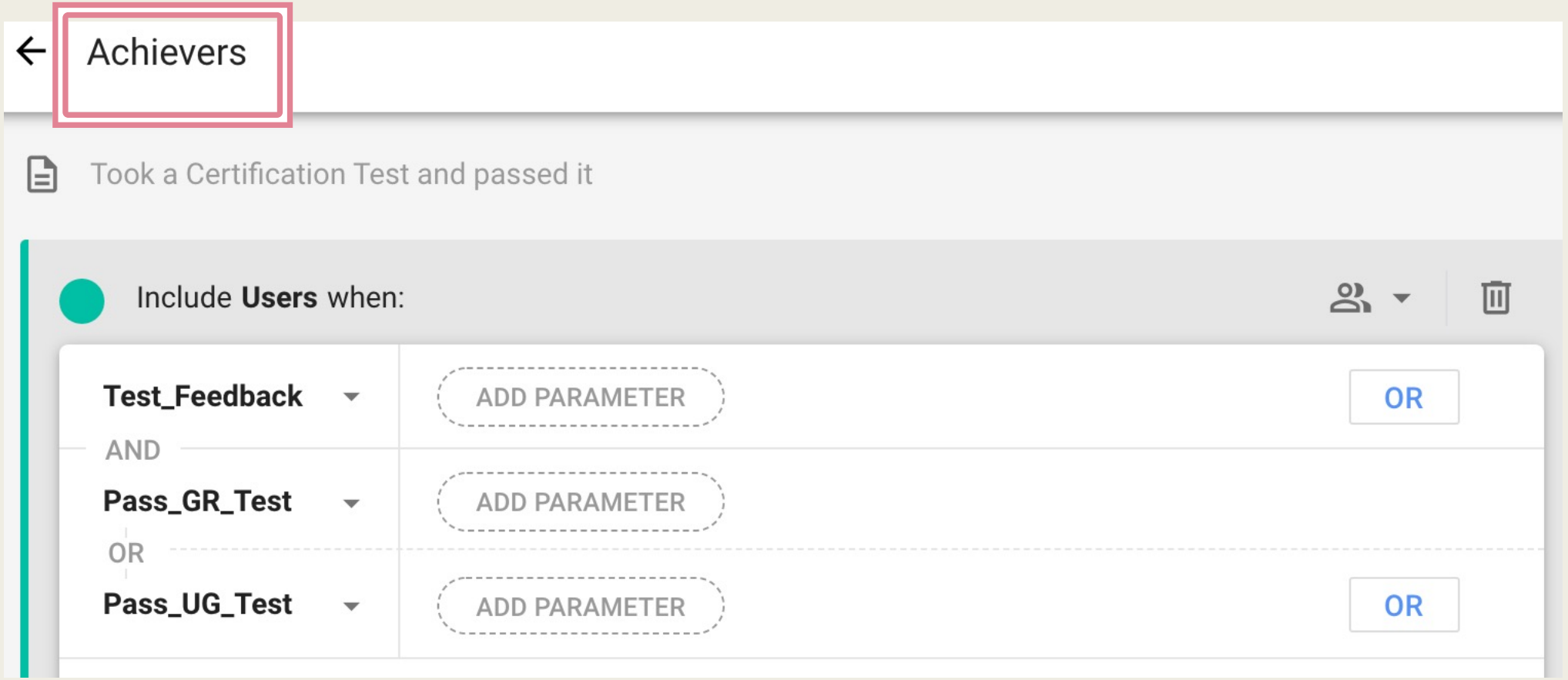
GA4 ANALYSIS PROCEDURES

Define GA4 segments needed for APT Queries

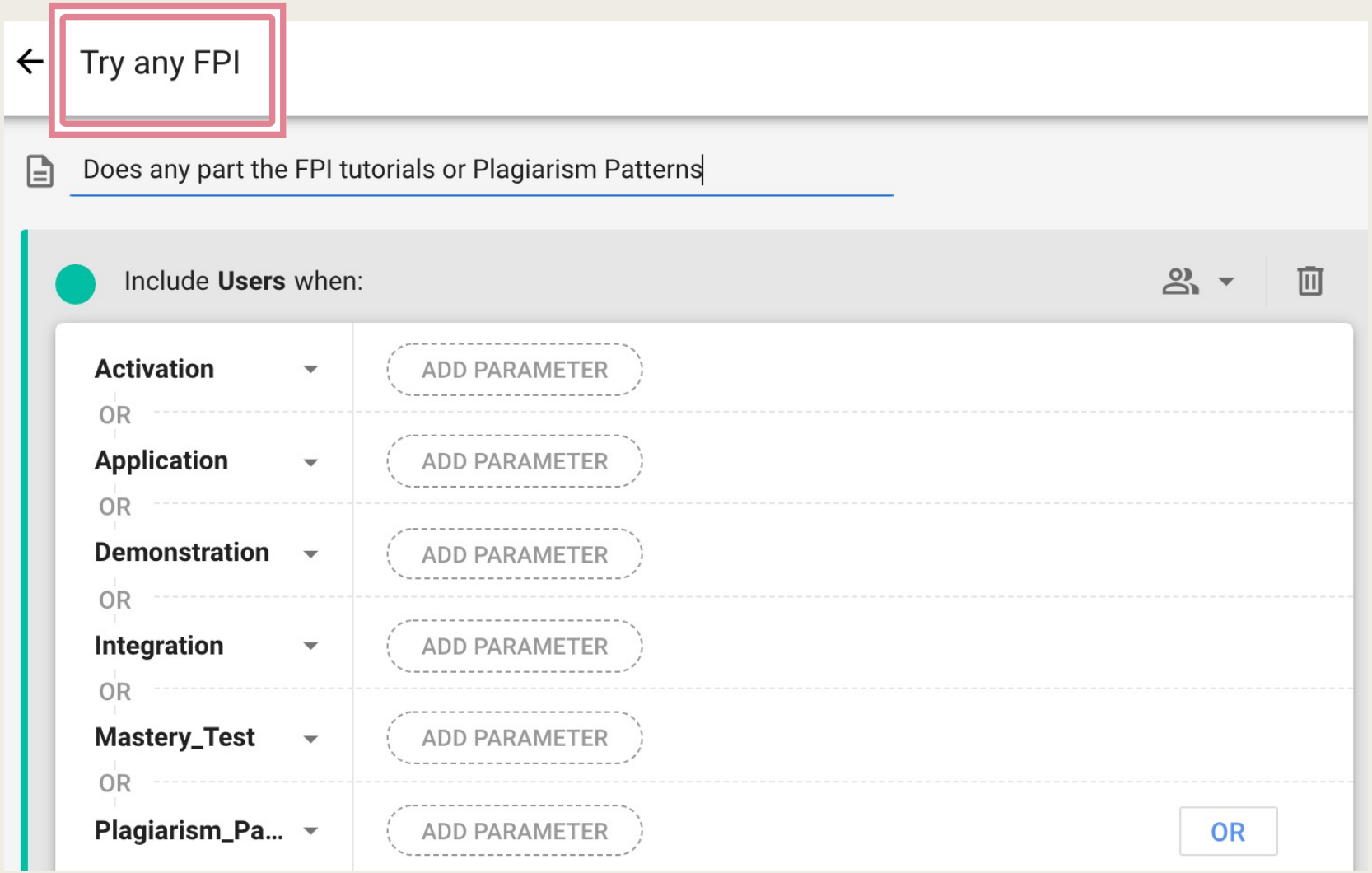
GA4 Segment Definition: for APT Queries

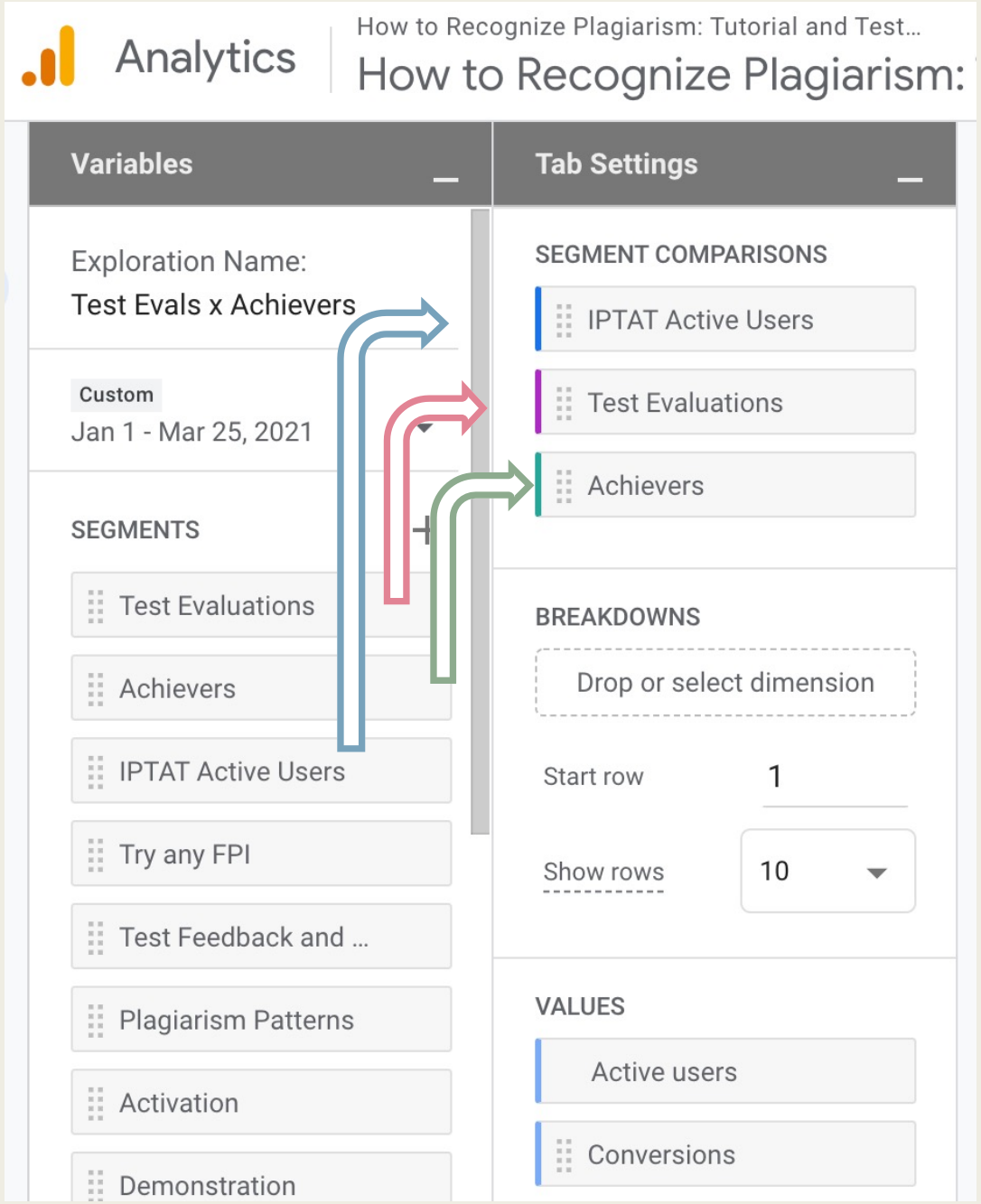


GA4 Segment Definition: for APT Queries



GA4 Segment Definition: for APT Queries



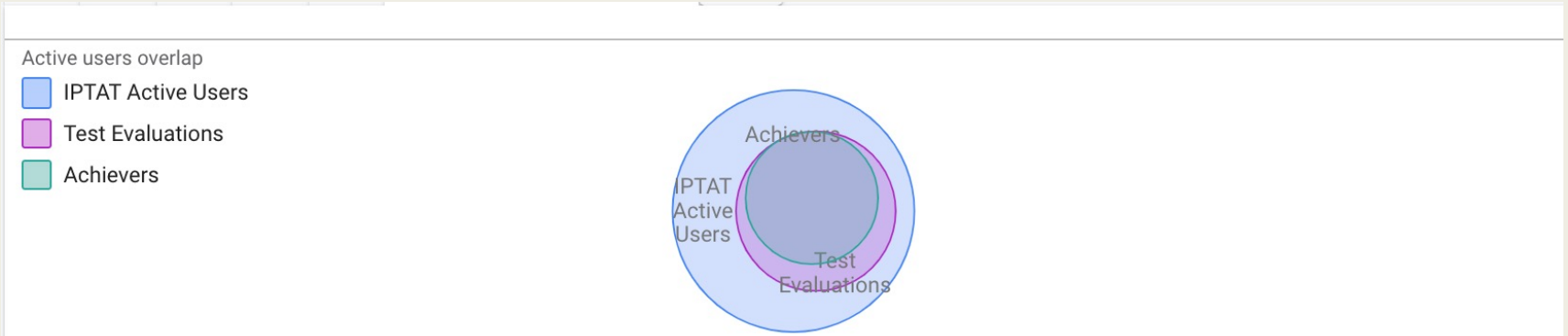


GA4 ANALYSIS:

SEGMENT OVERLAP SETUP

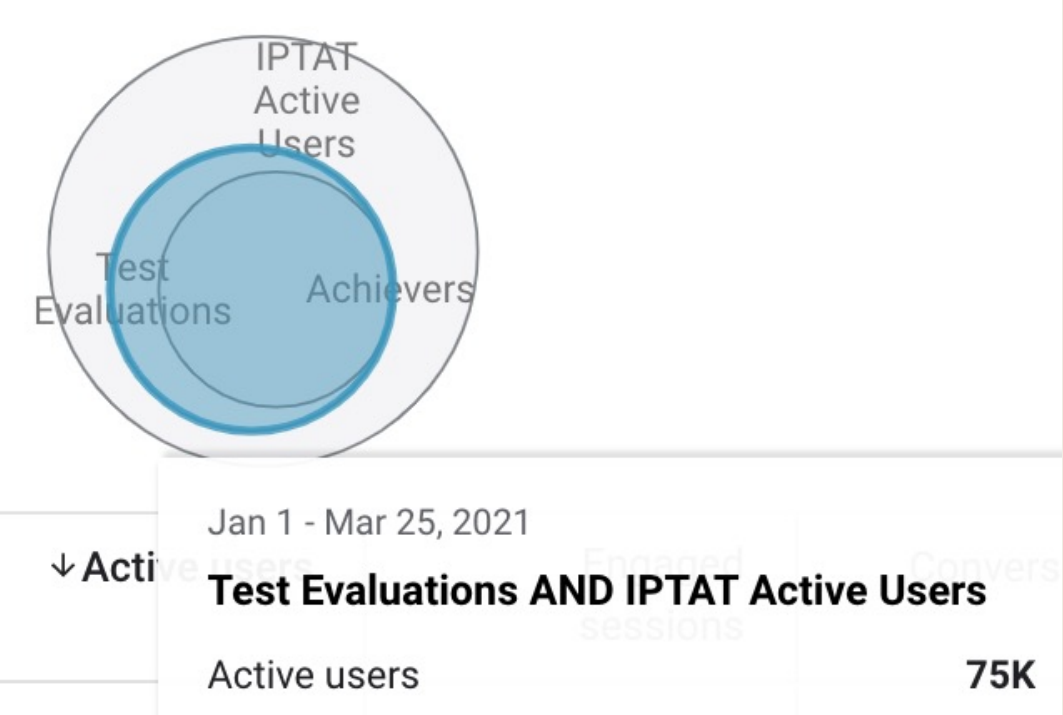
TO DO *APT QUERIES*

GA4 Segment Overlap Analysis Report: All Users

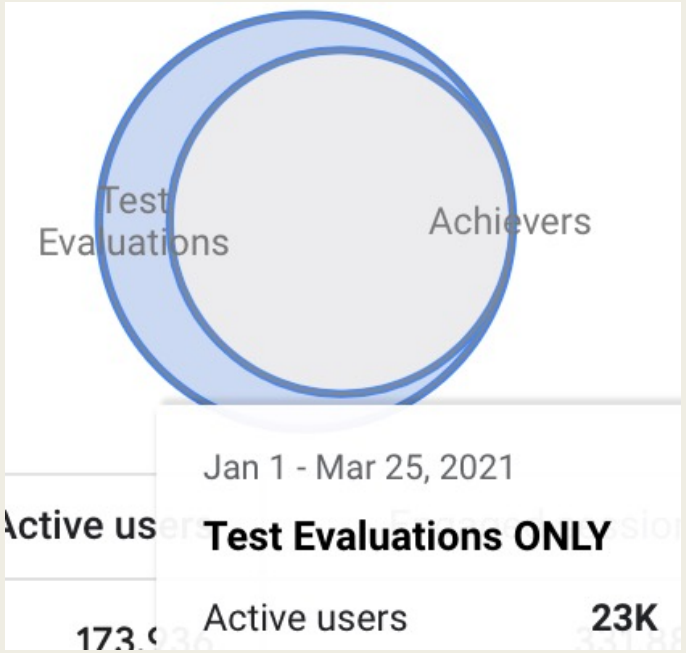


Segment set		↓ Active users	Engaged sessions	Conversions	User engagement
	Totals*	**173,936** 100% of total	**331,884** 100% of total	**16,547,092** 100% of total	**11y 110d** 100% of total
1	IPTAT Active Users	172,329	330,078	16,549,275	11y 109d
2	IPTAT Active Users ONLY	96,987	127,403	1,641,404	226d 23h
3	Test Evaluations	75,087	202,667	14,910,783	10y 248d
4	IPTAT Active Users + Test Evaluations	75,043	202,667	14,907,729	10y 247d
5	Achievers	51,648	135,943	11,212,373	7y 275d
6	Test Evaluations + Achievers	51,646	135,935	11,212,169	7y 275d

Exclude the Dabblers (97K). Keep those who have Test Evaluations (75K)



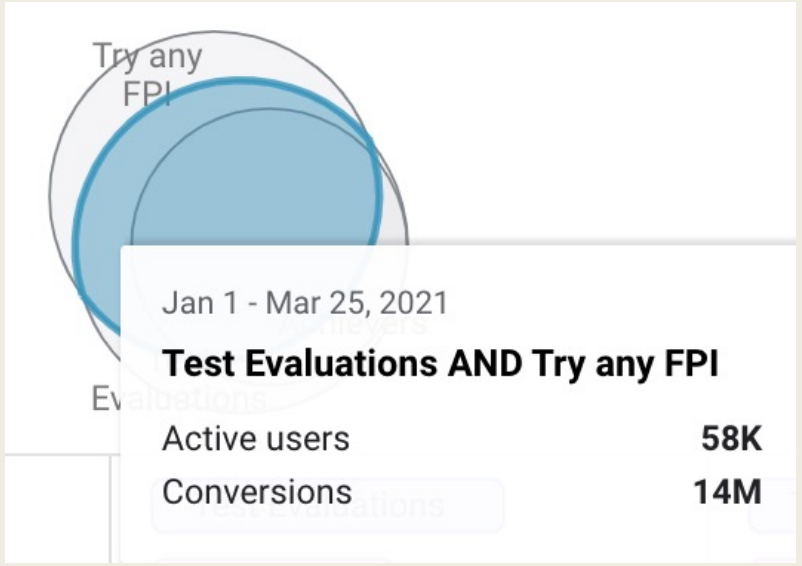
75K took 2 or more tests. 52K passed (Achievers); 23K did not pass (Nonmasters)

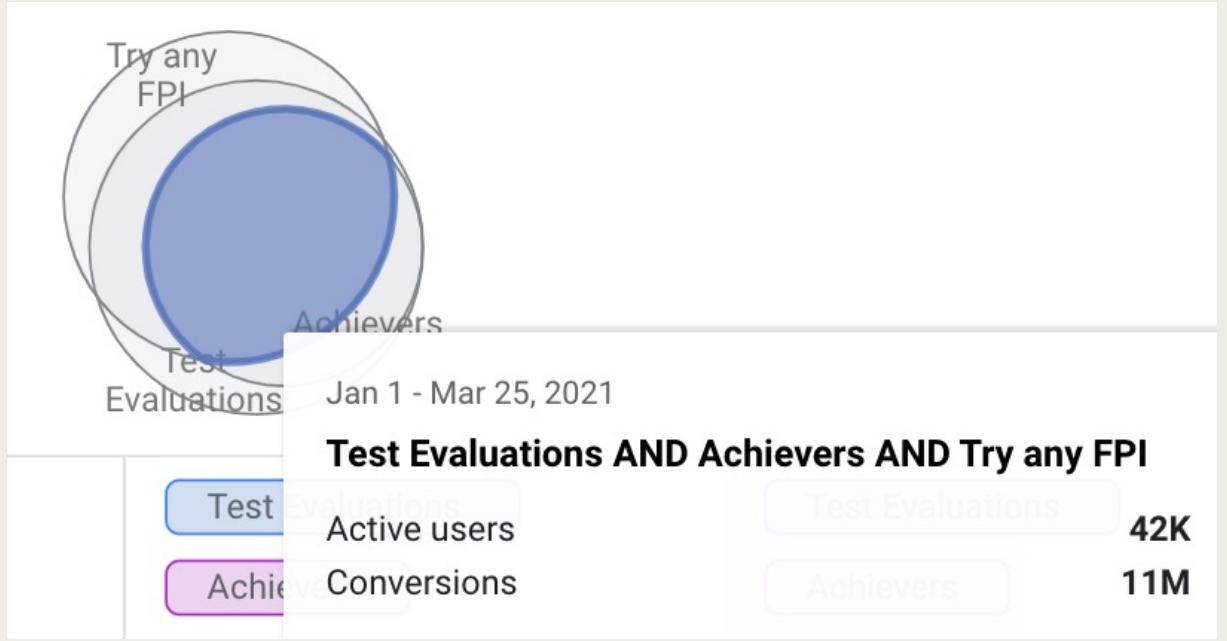


Segment Overlap: Remove Dabblers segment and add segment: Try any FPI

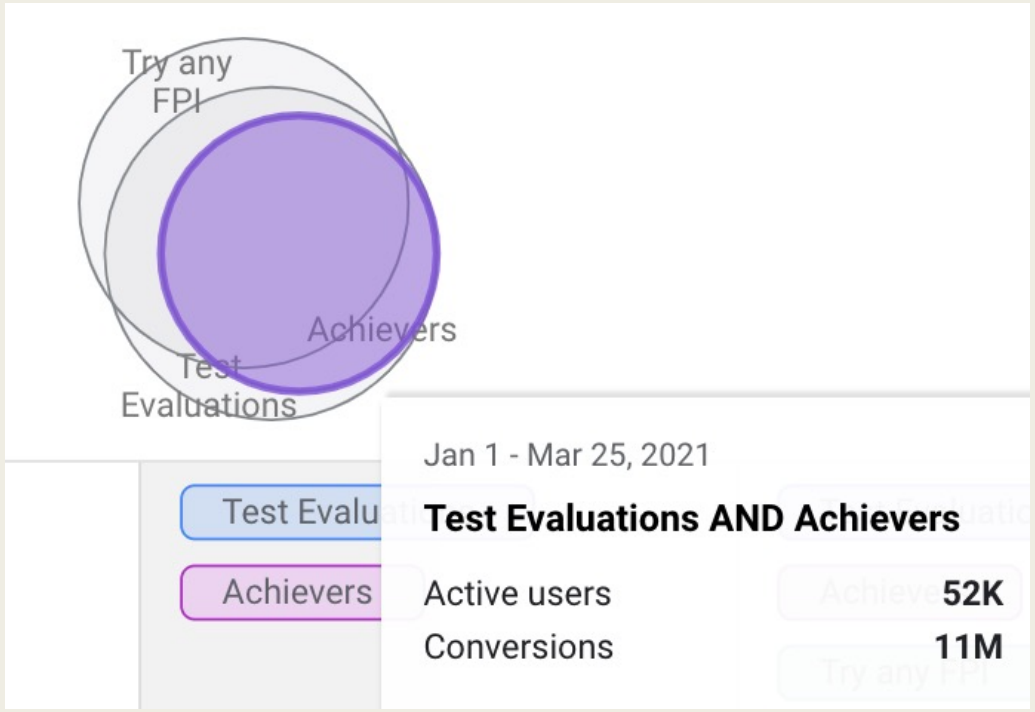
	Segment set	Test Evaluations, Try any FPI		Achievers		Test Evaluations, Achievers		Test Evaluations, Achievers, Try any FPI	
	Event name	Active users	Conversions	Active users	Conversions	Active users	Conversions	Active users	Conversions
10	Activation	27,604	350,283	21,416	281,842	21,416	281,842	21,416	281,842
11	Mastery_Test	27,392	695,593	21,488	554,001	21,488	554,001	21,488	554,001
12	Application	26,980	3,185,806	21,362	2,567,369	21,362	2,567,369	21,362	2,567,369
13	Demonstration	27,078	311,811	21,202	248,736	21,202	248,736	21,202	248,736
14	Integration	25,081	205,059	19,998	165,748	19,998	165,748	19,998	165,748
15	Pass_GR_Test	9,839	25,689	11,172	29,150	11,164	29,135	9,839	25,689

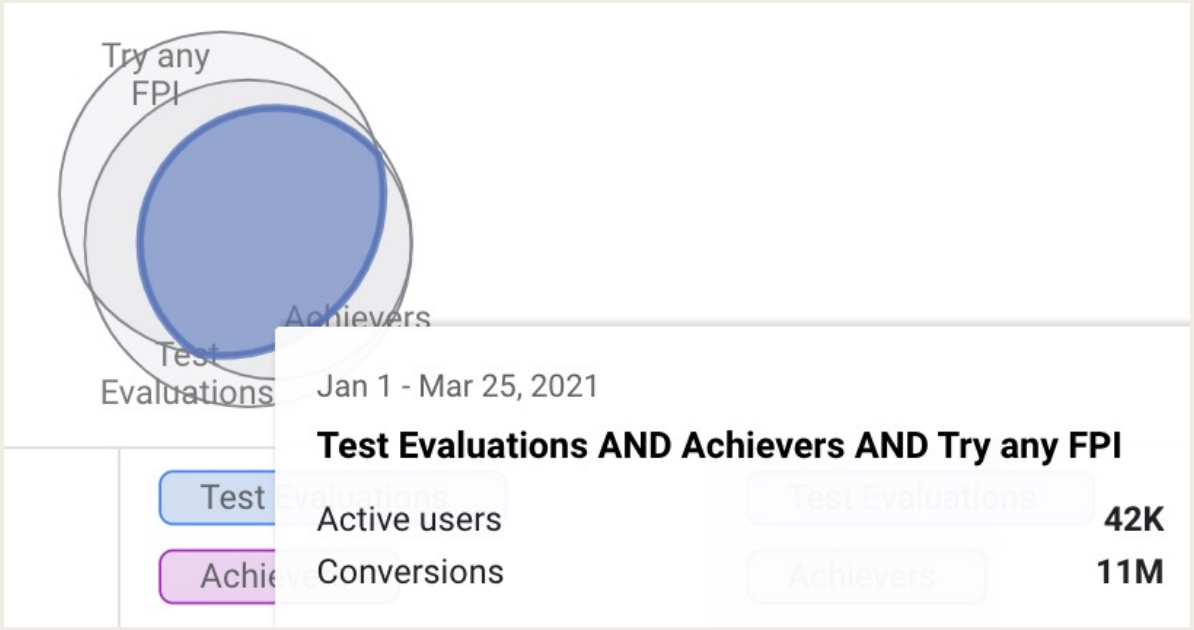
58K who took tests had Tried any FPI, and of those, 42K were Achievers.



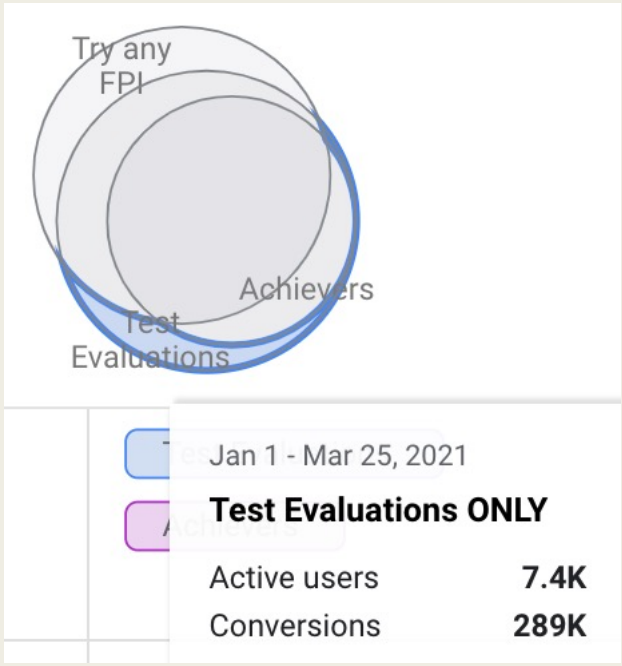


Since 52K passed, and 42K had Tried any FPI, then about 10K passed without trying any FPI (Minimalist Achievers)





23K had failed 2 or more tests (Nonmasters). 52K had passed (Achievers). 7.4K were Nonmasters who had *not* Tried any FPI. 23K - 7.4K = 15.6K were Nonmasters who *had* Tried any FPI.



APT Query Results

Segment set Event name	Achievers Active users	Achievers Conversions	Nonmasters Active users	Nonmasters Conversions
	51,648	11,212,373	23,405	3,702,581
page_view	51,648	4,338,323	23,405	1,427,673
Plagiarism_Test	51,648	1,015,210	23,405	514,313
Test_Feedback	51,648	1,158,217	23,405	542,610
Activation	21,416	281,842	6,108	68,526
Demonstration	21,202	248,736	5,871	63,163
Application	21,362	2,567,369	5,608	619,540
Integration	19,998	165,748	5,069	39,378
Mastery_Test	21,488	554,001	5,866	141,760
Plagiarism_Patterns	33,601	750,641	13,504	285,617
Pass_GR_Test	11,169	29,147	0	0
Pass_UG_Test	40,561	103,126	0	0

Segment set Event name	*p*(A)	*p*(N)	*p*(A | FPI)	*p*(N | FPI)	Odds (A:N)
Activation	0.29	0.08	0.78	0.22	3.51
Demonstration	0.28	0.08	0.78	0.22	3.61
Application	0.28	0.07	0.79	0.21	3.81
Integration	0.27	0.07	0.80	0.20	3.95
Mastery_Test	0.29	0.08	0.79	0.21	3.66
Plagiarism_Patterns	0.45	0.18	0.71	0.29	2.49

APT Query Results: Bayesian Outcomes

A Achiever
N Nonmaster
p probability
| given

FPI: First Principle of Instruction

SUMMARY

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)

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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

This presentation (PDF)

https://tedfrick.sitehost.iu.edu/apt/APTPresentationLabLA-ID.pdf