worldwidetelescope.org

wwtambassadors.org

Beyond-the-Book Thinking in Modern (STEM) Education

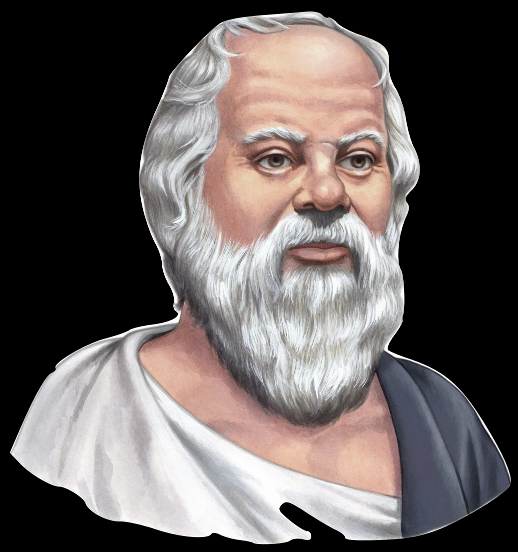
Alyssa A. Goodman

CENTER FOR ASTROPHYSICS HARVARD & SMITHSONIAN

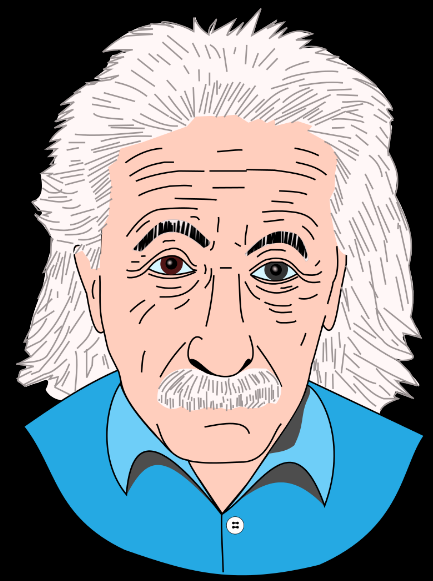
RADCLIFFE INSTITUTE FOR ADVANCED STUDY HARVARD UNIVERSITY

HarvardX

Socrates



Einstein



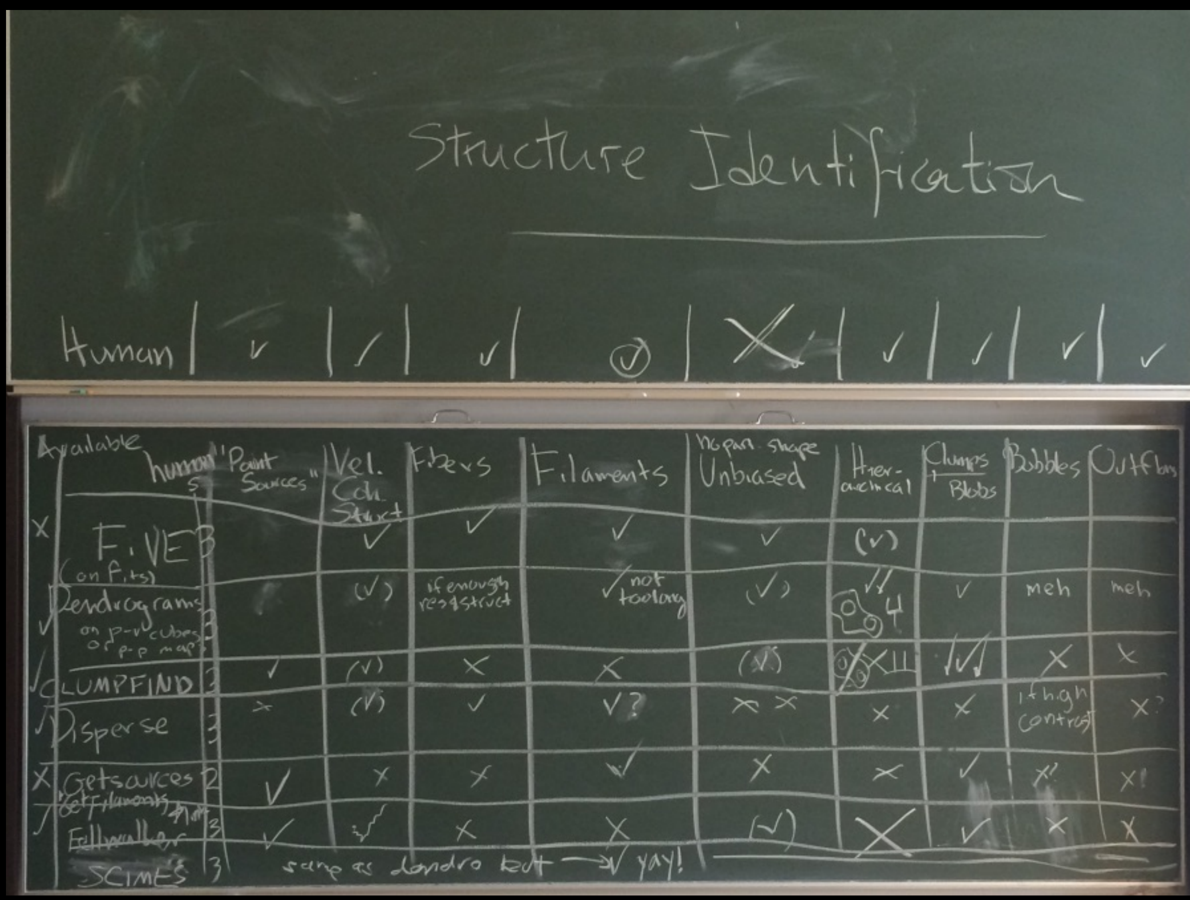
Streisand

“The more I learn, the less I know.”

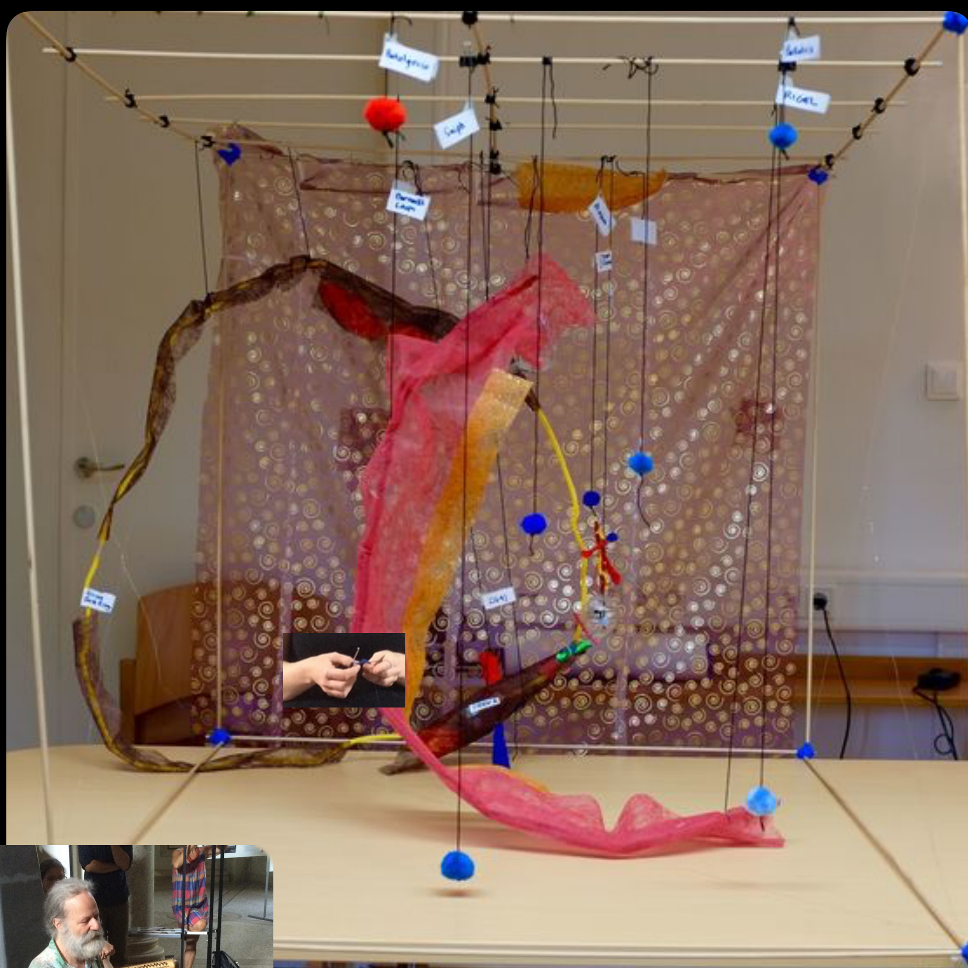

RADCLIFFE INSTITUTE
FOR ADVANCED STUDY
HARVARD UNIVERSITY
Friday, October 26, 2018
9:30 AM
Knafel Center
THE UNDISCOVERED
Many great discoveries in science are surprises

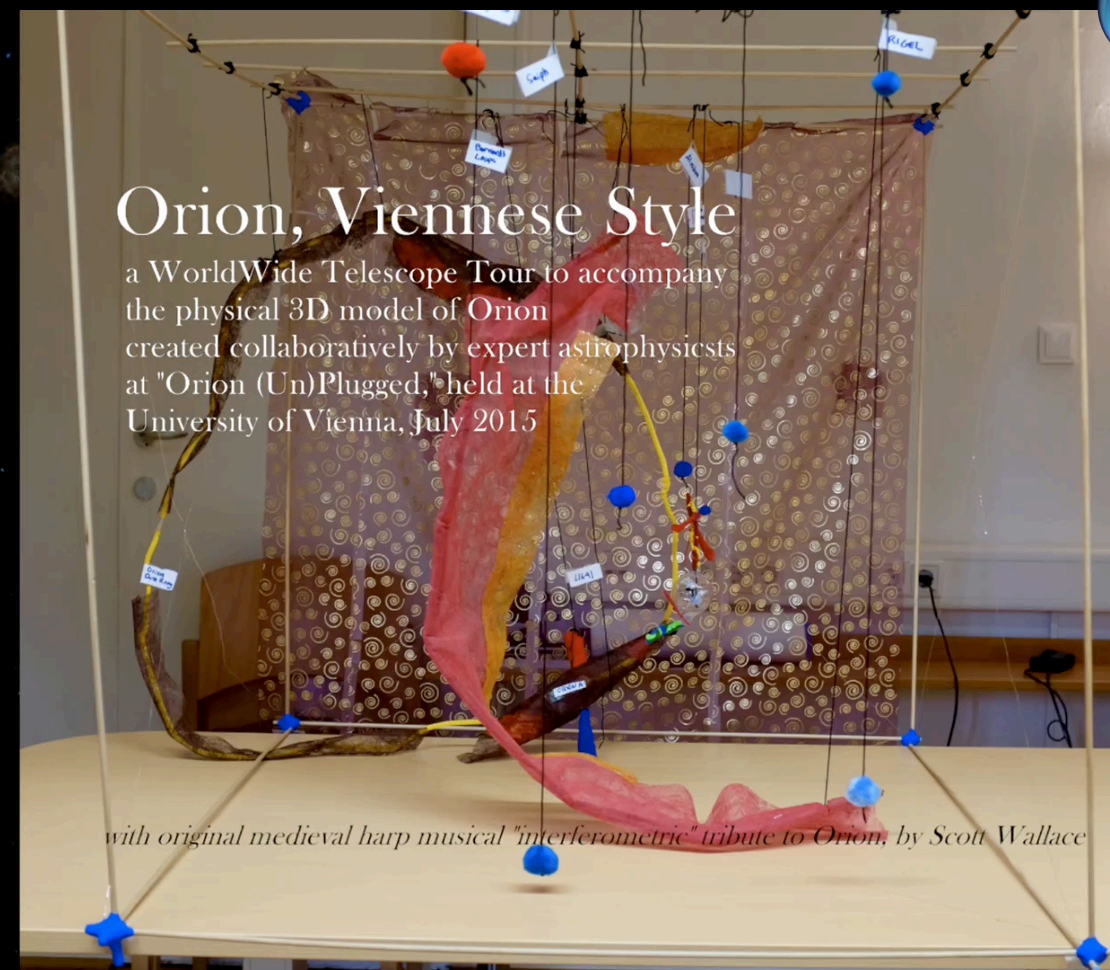
Barnstable High-School Senior Ceili Magnus at "The Undiscovered"
Radcliffe Institute for Advanced Study, October 26, 2018
https://youtu.be/BUIfWQU7IsU?t=834

VIENNA

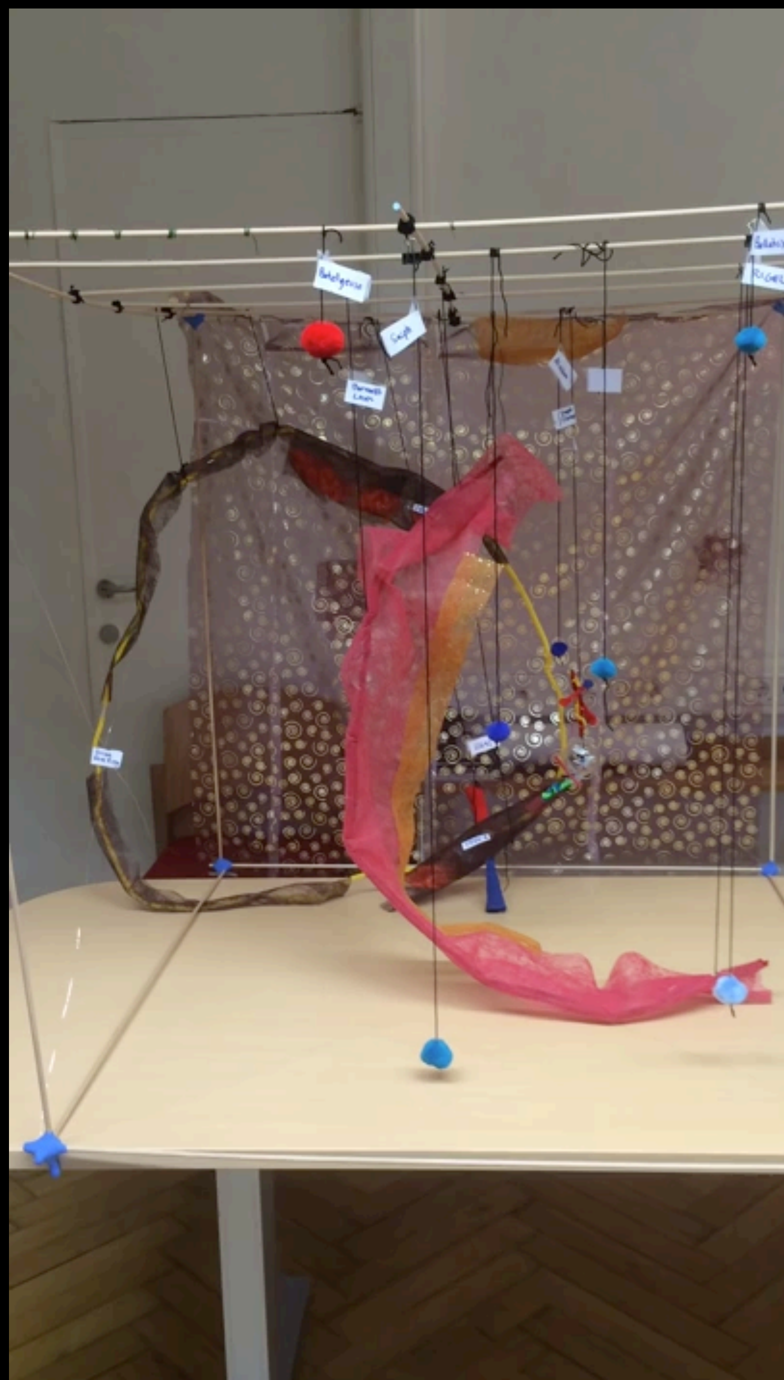

Structure Identification
Human
Filaments
Unbiased
Dendrograms
CLUMPFIND
Disperse
Getsources
SCIMES
yay!

VIENNA




Orion, Viennese Style
a WorldWide Telescope Tour to accompany
the physical 3D model of Orion
created collaboratively by expert astrophysicsts
at "Orion (Un)Plugged," held at the
University of Vienna, July 2015
with original medieval harp musical "interferometric" tribute to Orion, by Scott Wallace

VIENNA



A&A 587, A153 (2016)
DOI: 10.1051/0004-6361/201527160

Astronomy & Astrophysics

VISION – Vienna survey in Orion

I. VISTA Orion A Survey⋆,⋆⋆

Stefan Meingast[1], João Alves[1], Diego Mardones[2], Paula Stella Teixeira[1], Marco Lombardi[3], Josefa Großschedl[1], Joana Ascenso[4,5], Herve Bouy[6], Jan Forbrich[1,7], Alyssa Goodman[7], Alvaro Hacar[1], Birgit Hasenberger[1], Jouni Kainulainen[8], Karolina Kubiak[1], Charles Lada[7], Elizabeth Lada[9], André Moitinho[10], Monika Petr-Gotzens[11], Lara Rodrigues[2], and Carlos G. Román-Zúñiga[12]

1 Department of Astrophysics, University of Vienna, Türkenschanzstrasse 17, 1180 Wien, Austria
e-mail: stefan.meingast@univie.ac.at
2 Departamento de Astronomía, Universidad de Chile, Casilla 36-D, Santiago, Chile
3 University of Milan, Department of Physics, via Celoria 16, 20133 Milan, Italy
4 CENTRA, Instituto Superior Tecnico, Universidade de Lisboa, Av. Rovisco Pais 1, 1049-001 Lisbon, Portugal
5 Universidade do Porto, Departamento de Engenharia Física da Faculdade de Engenharia, Rua Dr. Roberto Frias, s/n, 4200-465 Porto, Portugal
6 Centro de Astrobiología, INTA-CSIC, Depto Astrofísica, PO Box 78, 28691 Villanueva de la Cañada, Madrid, Spain
7 Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA
8 Max-Planck-Institute for Astronomy, Königstuhl 17, 69117 Heidelberg, Germany
9 Astronomy Department, University of Florida, Gainesville, FL 32611, USA
10 SIM/CENTRA, Faculdade de Ciencias de Universidade de Lisboa, Ed. C8, Campo Grande, 1749-016 Lisboa, Portugal
11 European Southern Observatory, Karl-Schwarzschild-Str. 2, 85748 Garching, Germany
12 Instituto de Astronomía, UNAM, Ensenada, CP 22860, Baja California, Mexico

Received 10 August 2015 / Accepted 1 December 2015

ABSTRACT

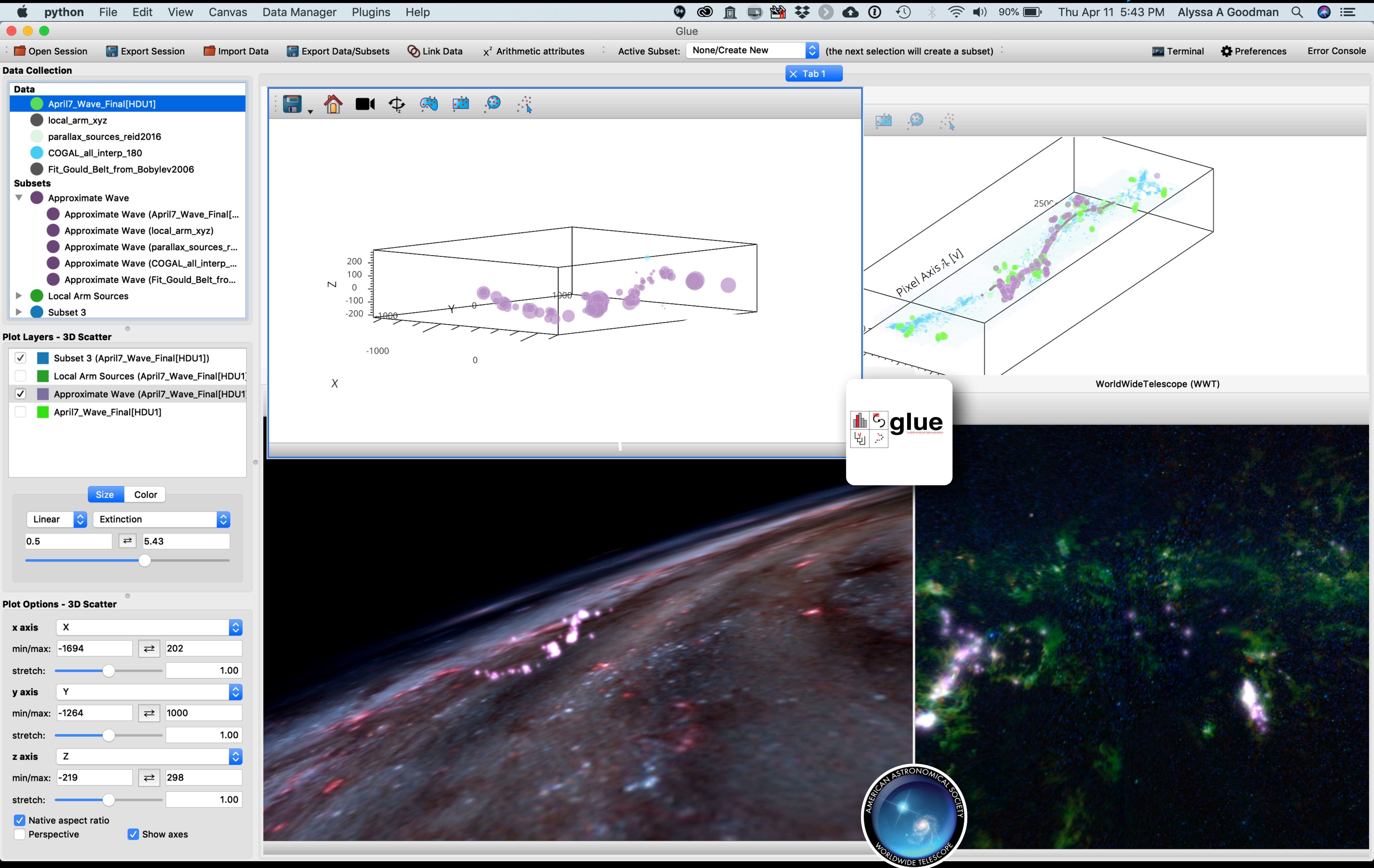
Context. Orion A hosts the nearest massive star factory, thus offering a unique opportunity to resolve the processes connected with the formation of both low- and high-mass stars. Here we present the most detailed and sensitive near-infrared (NIR) observations of the entire molecular cloud to date.
Aims. With the unique combination of high image quality, survey coverage, and sensitivity, our NIR survey of Orion A aims at establishing a solid empirical foundation for further studies of this important cloud. In this first paper we present the observations, data reduction, and source catalog generation. To demonstrate the data quality, we present a first application of our catalog to estimate the number of stars currently forming inside Orion A and to verify the existence of a more evolved young foreground population.
Methods. We used the European Southern Observatory's (ESO) Visible and Infrared Survey Telescope for Astronomy (VISTA) to survey the entire Orion A molecular cloud in the NIR J, H, and K_S bands, covering a total of ~18.3 deg^2. We implemented all data reduction recipes independently of the ESO pipeline. Estimates of the young populations toward Orion A are derived via the K_S-band luminosity function.
Results. Our catalog (799 995 sources) increases the source counts compared to the Two Micron All Sky Survey by about an order of magnitude. The 90% completeness limits are 20.4, 19.9, and 19.0 mag in J, H, and K_S, respectively. The reduced images have 20% better resolution on average compared to pipeline products. We find between 2300 and 3000 embedded objects in Orion A and confirm that there is an extended foreground population above the Galactic field, in agreement with previous work.

AMERICAN ASTRONOMICAL SOCIETY
WORLDWIDE TELESCOPE

worldwidetelescope.org

wwtambassadors.org

The Undiscovered, yesterday



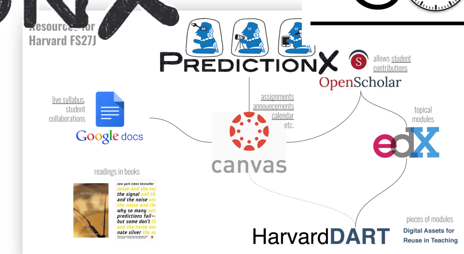
2012

2008

2013

PredictionX

2015-

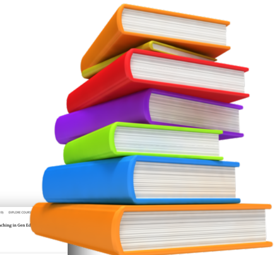


2015-18

The TIMELINE CONSORTIUM

2016-

2020

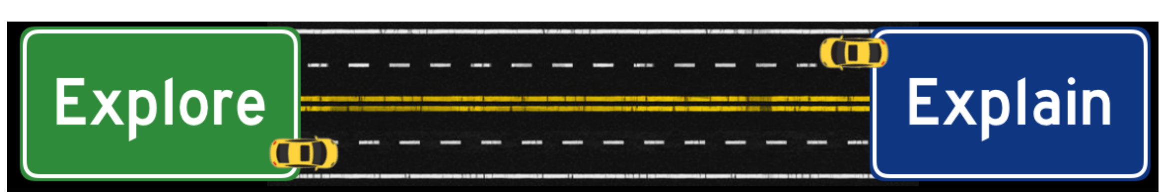


2020-?

(Paths to) today.

Viz

2017-

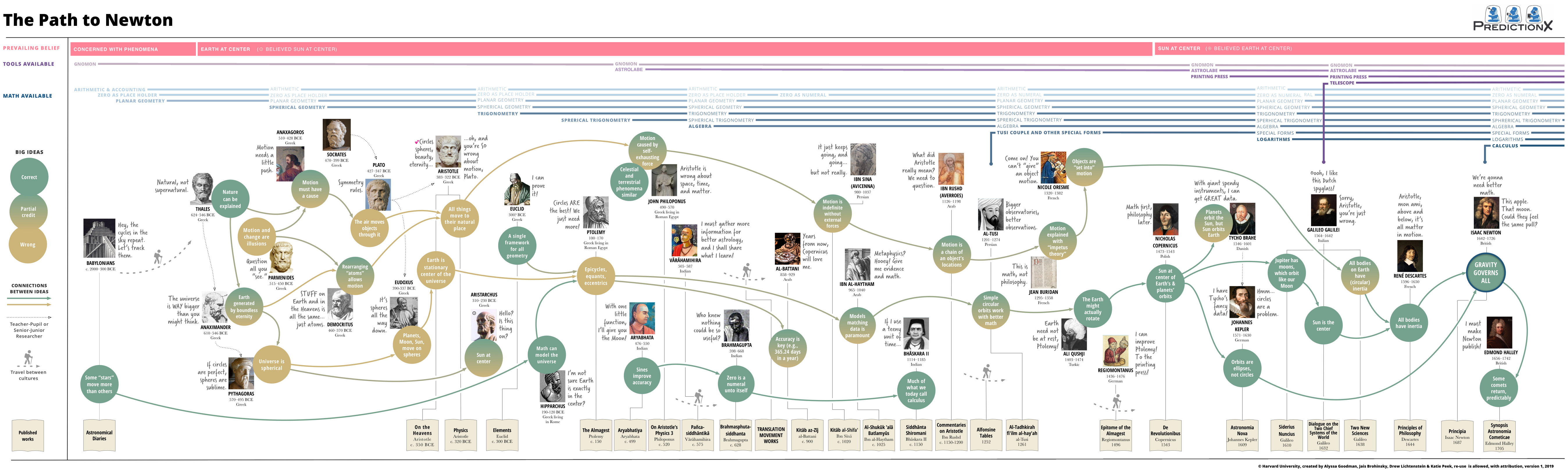


2018

2018

2019

The Path to Newton



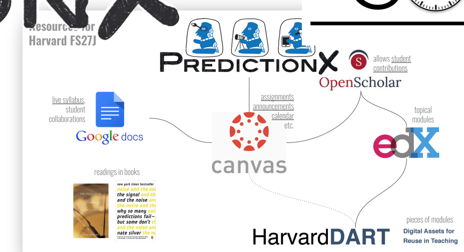
2012

2008

2013

PredictionX

2015-

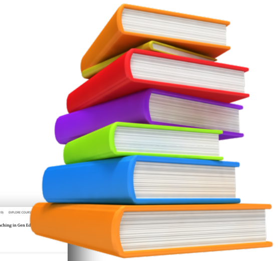


2015-18

The TIMELINE CONSORTIUM

2016-

2020

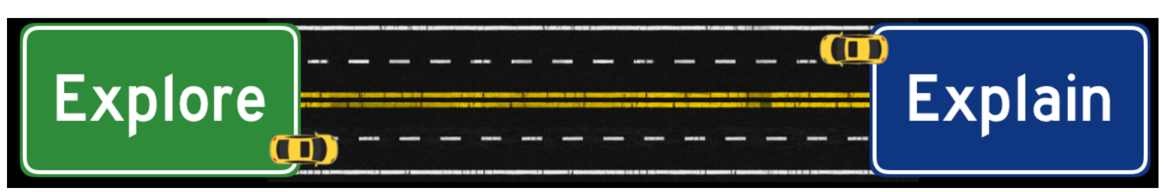


2020-?

(Paths to) today.

10 Viz

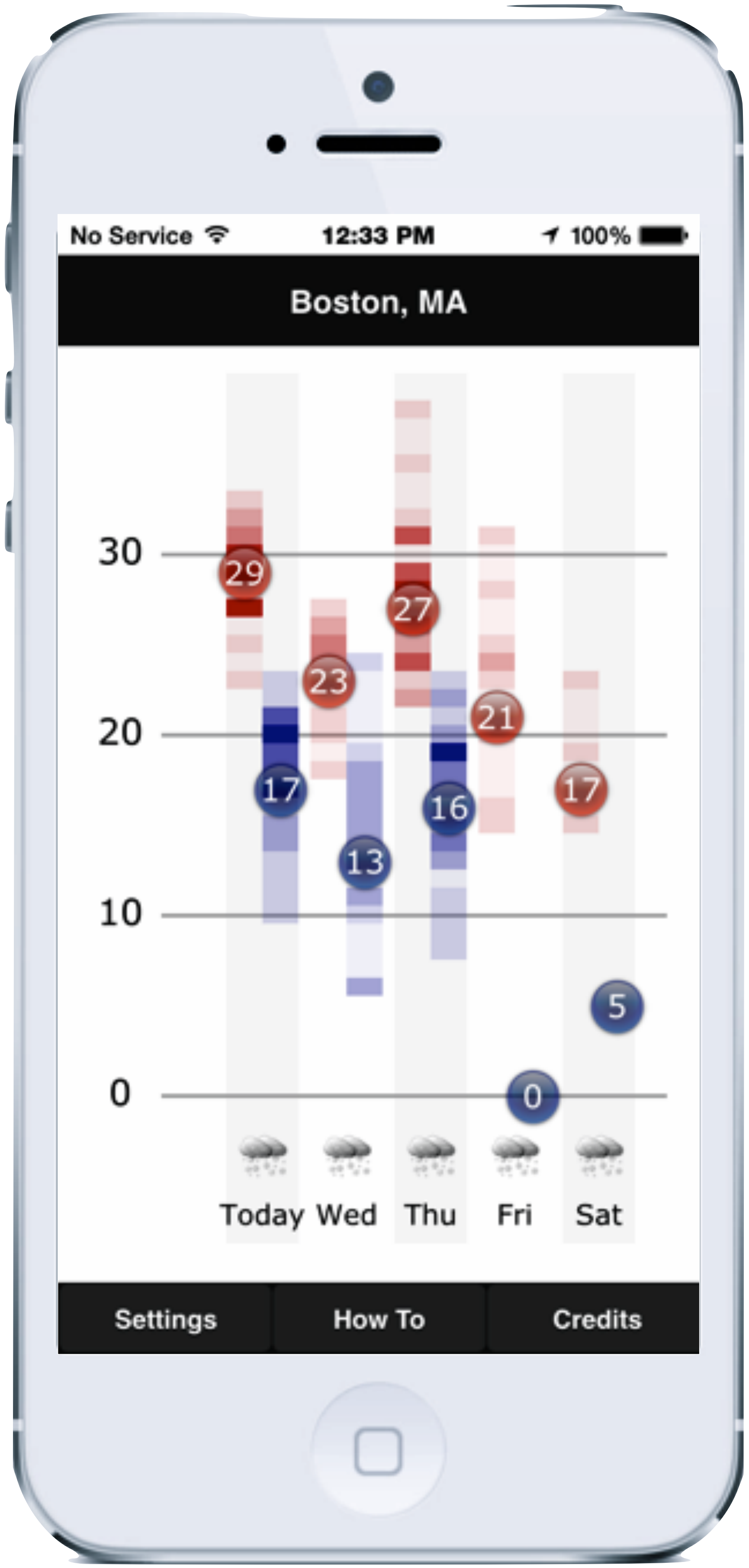
2017-



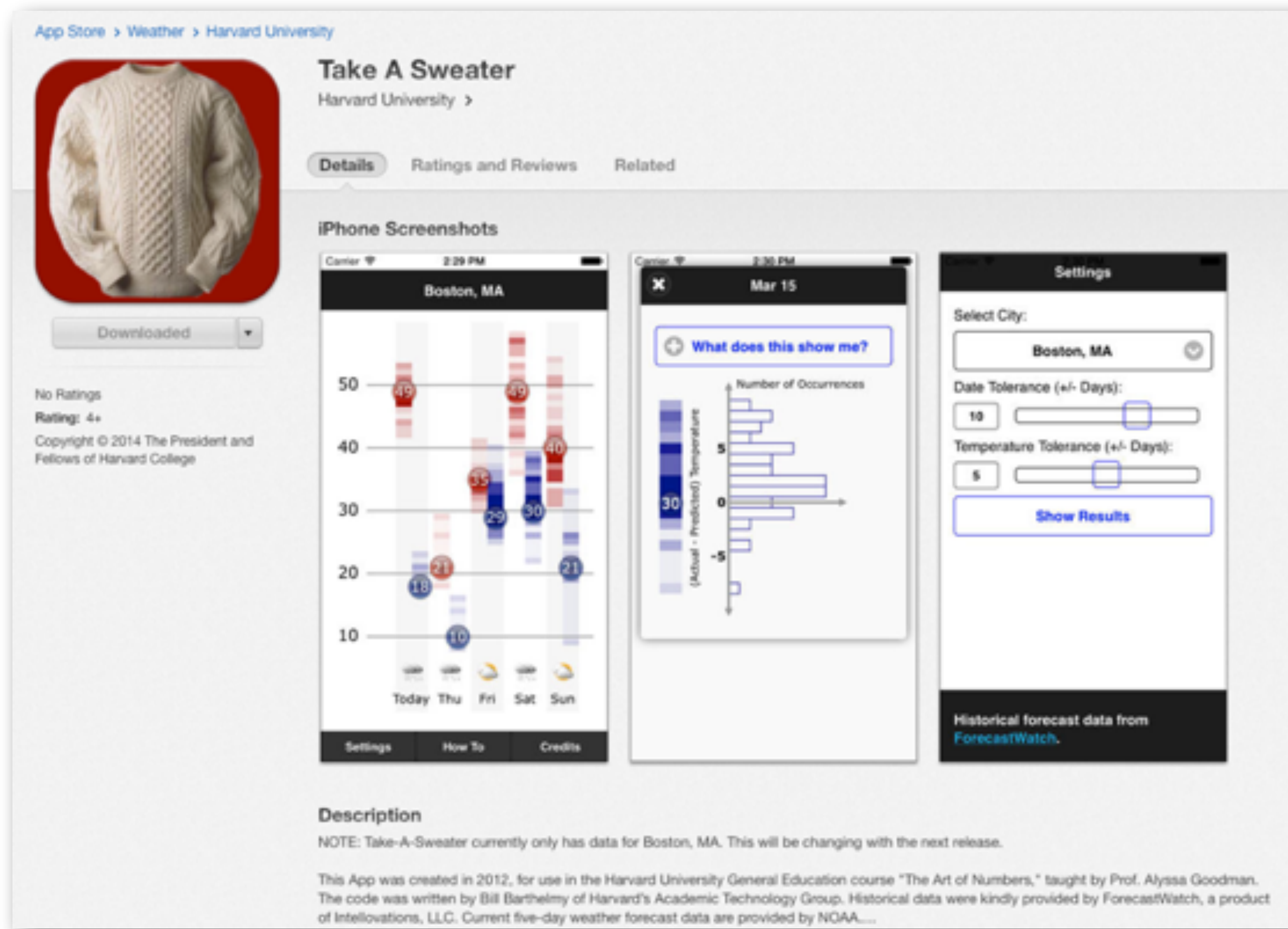
2018

2018

2019



"Take A Sweater"



takeasweater.com, and "TakeASweater" in the Apple App Store

with thanks to Eric **Floehr** of Forecast Watch and Bill **Barthelmy** of HUIT Academic Technology at FAS

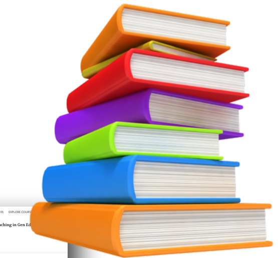
2012

PredictionX

2015-

The TIMELINE CONSORTIUM

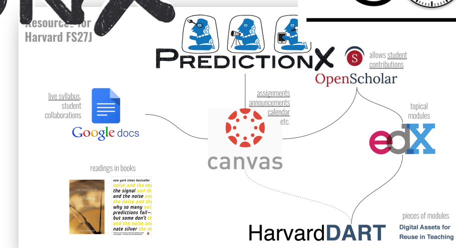
2016-



2020-?

2008

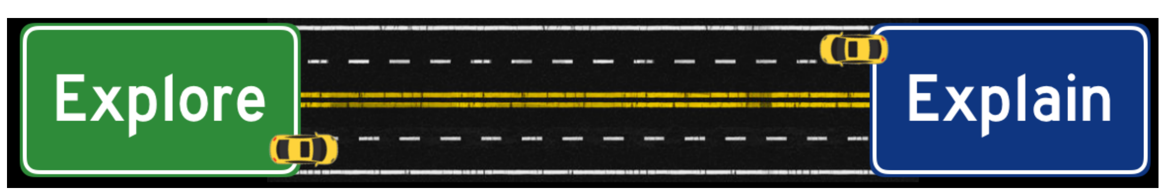
2013



2015-18

2020

(Paths to) today.



2017-

2018

2018

2019

HARVARD ASTRONOMY 201B

ISM and Star Formation

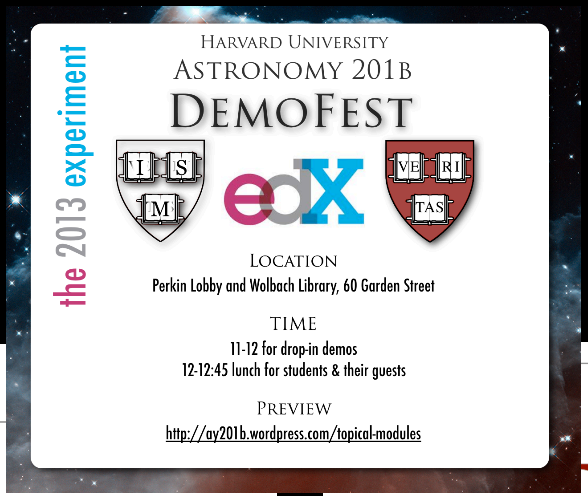
“THE BOOK” | HANDOUTS | JOURNAL CLUB | TOPICAL MODULES | AY208 NOTES (2000) | ISITE

Our Jointly-Edited Online “Book”

This “book” accompanies the Harvard University graduate course Astronomy 201b, “The Interstellar Medium and Star Formation.” The first incarnation was created in 2011 by Prof. Alyssa Goodman, Teaching Fellow Chris Beaumont, and the 21 Harvard graduate students who took the course at that time. The “book” will continue to evolve throughout Spring 2013 as student contributions from this new instance of the course are added.

Links at the top of each section (in orange) are slides and notes from this year (2013), sorted by date. They will be posted within one day of the class date. Links in red are transcriptions of Alyssa Goodman’s notes, originally from 2011 and updated throughout the semester as we discuss each topic. Links in green are student contributions from 2011. Links in blue are transcriptions from guest lecturers. Links in violet are the class handouts and weblinks which can (hopefully!) be posted here without copyright violation.

Student contributions from 2011 are shown in dark green. Online modules developed by the AY201b students at Harvard in 2013 are listed here.



HARVARD ASTRONOMY 201B

ISM and Star Formation

“THE BOOK” | HANDOUTS | JOURNAL CLUB | TOPICAL MODULES | AY208 NOTES (2000) | ISITE

Topical Modules

Harvard Astronomy 201b: Interactive Software Modules Created by Students

Click here to see modules created by students in the Spring 2013 term.

For a full description of the module creation process, motivations, and outcomes, see our article arXiv:1308.1908.

Cornell University Library

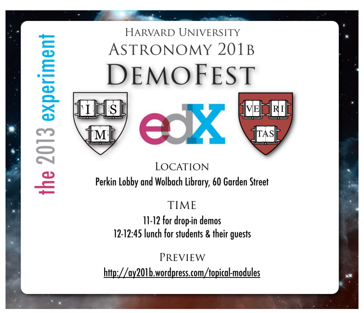
arXiv.org > physics > arXiv:1308.1908

Physics > Physics Education

A New Approach to Developing Interactive Software Modules through Graduate Education

Nathan E. Sanders, Chris Faesi, Alyssa A. Goodman (Harvard University)

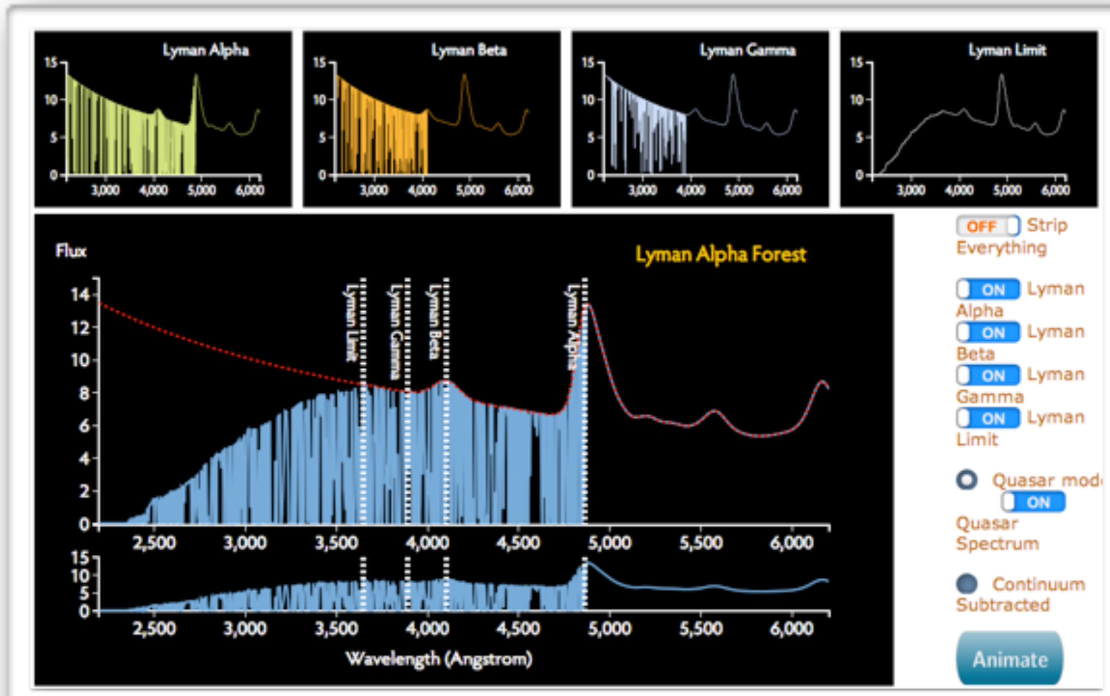
(Submitted on 8 Aug 2013)



Stephen

Yuan-Sen **Ting**

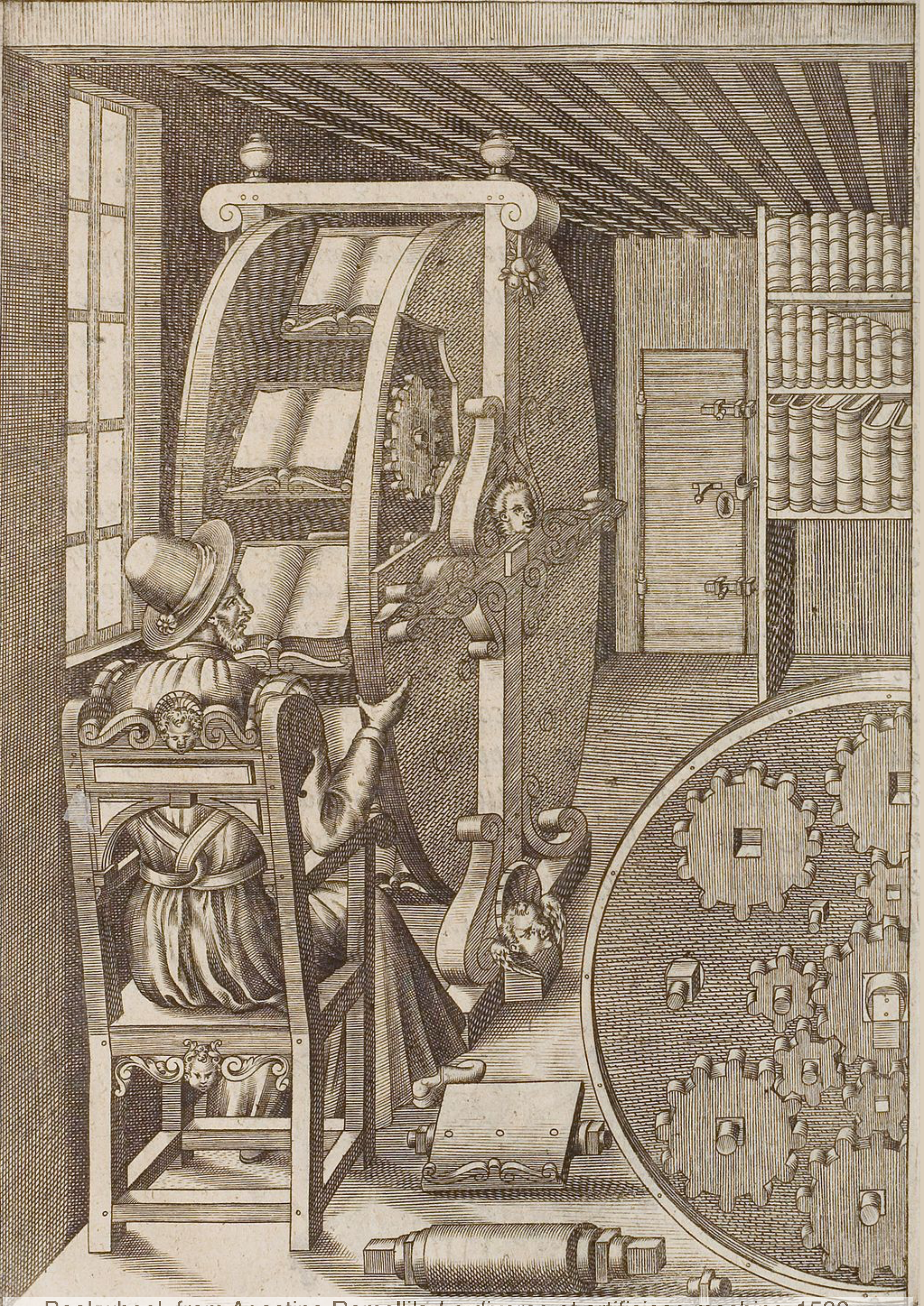
Interstellar Absorption and the Lyman Alpha Forest



JavaScript https://www.cfa.harvard.edu/~yuan-sen.ting/lyman_alpha.html

JavaScript http://portillo.ca/nebula/

see: A New Approach to Developing Interactive Software Modules through Graduate Education, Sanders, Faesi & Goodman 2013


Bookwheel, from Agostino Ramelli's *Le diverse et artificiose machine*, 1588.

"Do kids read?"

"Textbooks are stupid—Wikipedia is way better!" (Caveats: may be different in different subjects—science textbooks may be useful; novels, history books, etc. still awesome.)

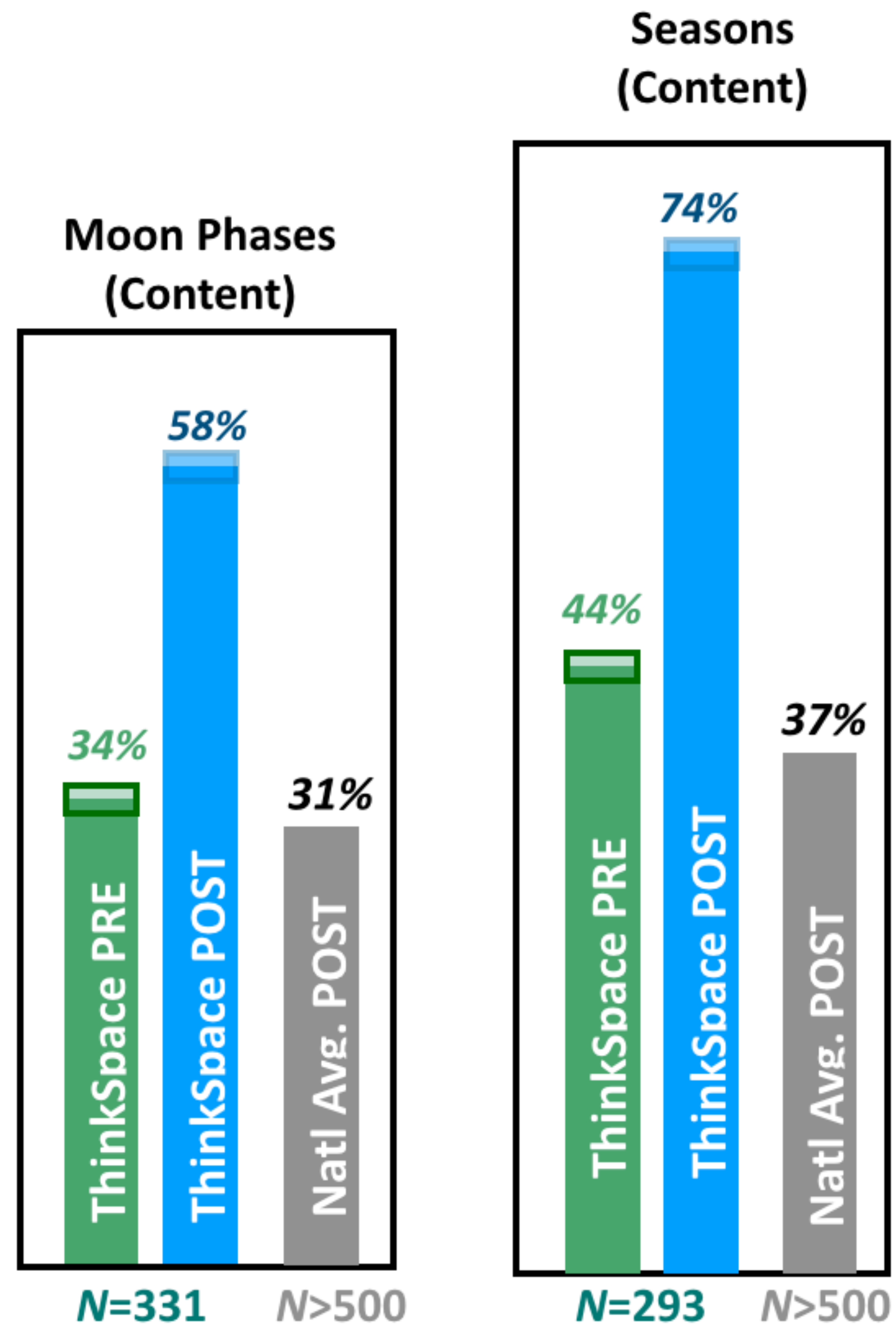
"People my age are digesting way more information, e.g. many YouTube videos way more intelligent & philosophically complex than television news."

What about evaluation?

"More effort & time required."
"Un-assessed work, like blog posts, are fine."
"Factory system doesn't prepare you for the real world."
"Why expect everyone to learn exactly the same thing?"

Thanks to Joan Najita, Sharmila Dey & Abby Schwartz for insights here.

Sample ThinkSpace results…
Pre (green) vs. Post (blue) Content Scores
for Moon Phases and Seasons,
compared with National Averages
of delayed post- "business as usual" instruction
(N>500) from Sadler et al., 2010 (gray).



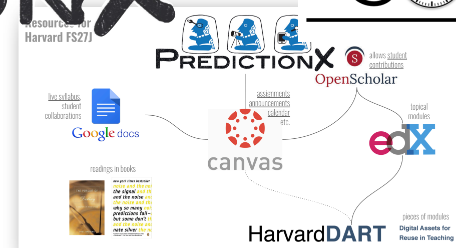
2012

2008

2013

PredictionX

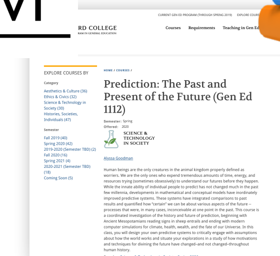
2015-



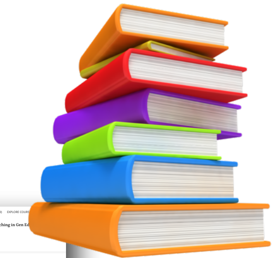
2015-18

The TIMELINE CONSORTIUM

2016-



2020

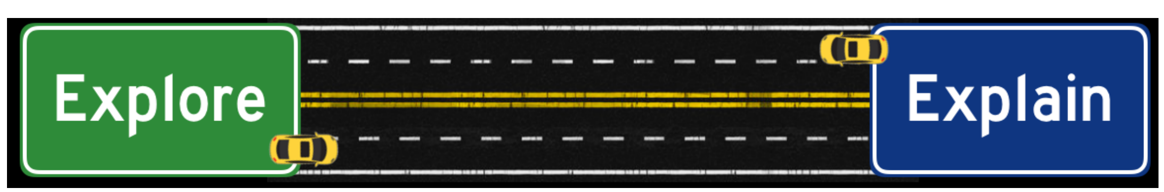


2020-?

(Paths to) today.

10 Viz

2017-



2018

2018

2019

PredictionX

PredictionX: The Past & Present of the Future

Tools

- **Framework for Predictive Systems** (edX)
- **Framework for Study Design**
- **Understanding Uncertainty** (interactive)
- **Timelines** (interactive)
- **Why predict?** (video)

Omens, Oracles & Prophecies

(edX)

- Mesopotamian Haruspicy
- Roman Augury
- Chinese Oracle Bones
- Oracle of Delphi
- Aztec Rituals
- Egyptian Priests
- Tarot
- **The Diviner's Guide**
- Turkish Tasseography
- Maya Spacetime
- Yoruba Ifa
- Casting Lots
- *Greek Astronomy*
- Astrology
- Comets of Doom
- **cross-cultural conversations**

The Rise of Theory

- Islamic Science
- The Royal Society
- **John Snow & Cholera** (edX)
  - Cholera Map (interactive)
- **The Path to Newton**
- **Lost without Longitude (Navigation)** (edX)
- Indian Mathematics (video)
- Tools of the Navigator (edX)
- Help, I'm Lost! (interactive, edX)

Modern Simulation

Health
- Epidemiology (video)
- Personal Genomics (video)

Earth
- Earthquakes
- Climate Change
- Tent Tarot (video, edX)

Wealth
- Personal Finance
- World Economy

Space
- Futures of our Universe

The Future of the Future
- Artificial Intelligence (video)
- Derek's Day (interactive)

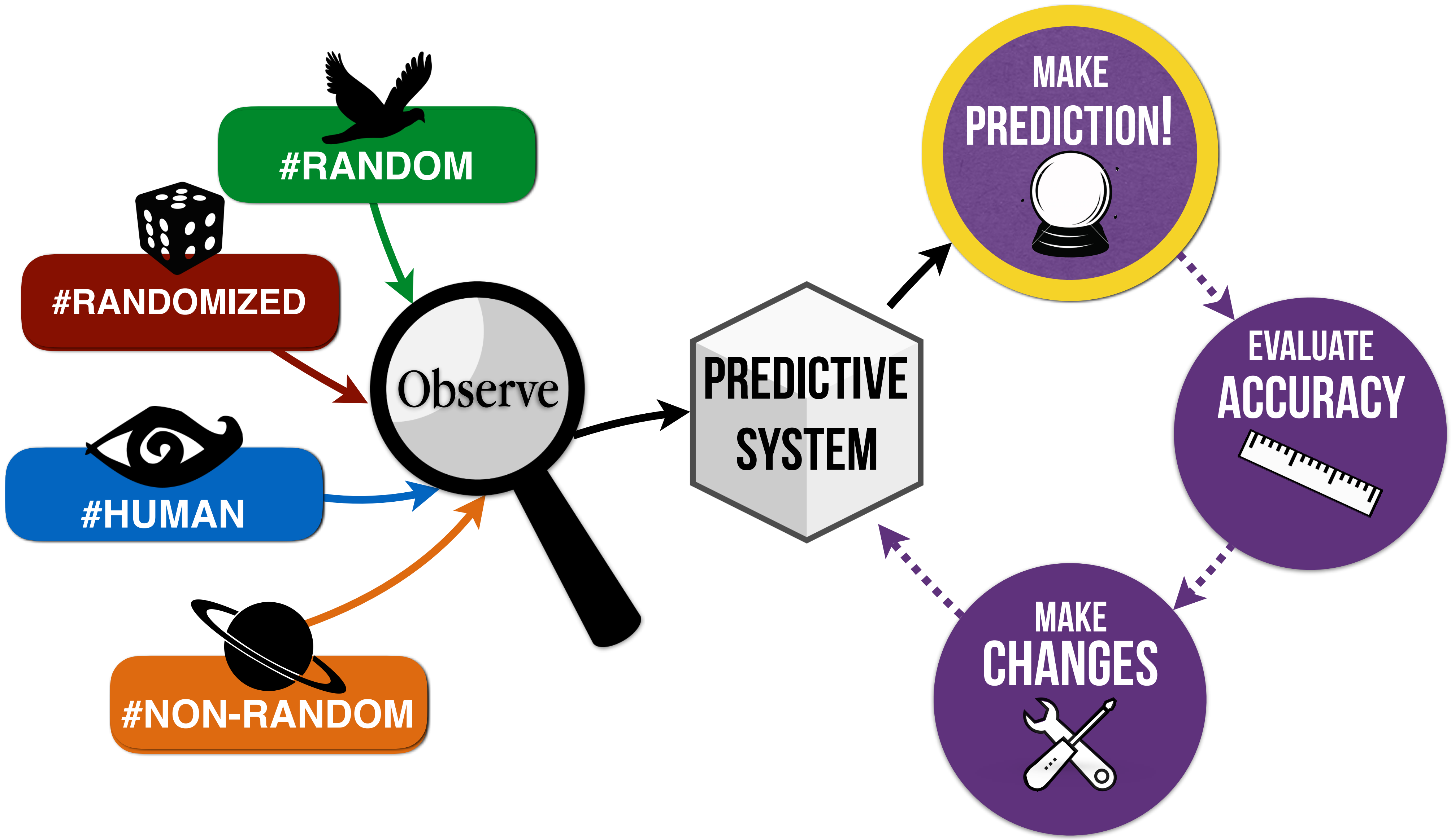
Finished | Coming Soon | Planned | Interactive Resource | ▶ video(s) | edX link to edX (often contains videos + interactives, not marked separately here)

HarvardX · general education · edX · predictionx.org

with many thanks to HarvardX course producer Drew Lichtenstein, research assistant Jais Brobinsky + dozens of other experts at Harvard and beyond

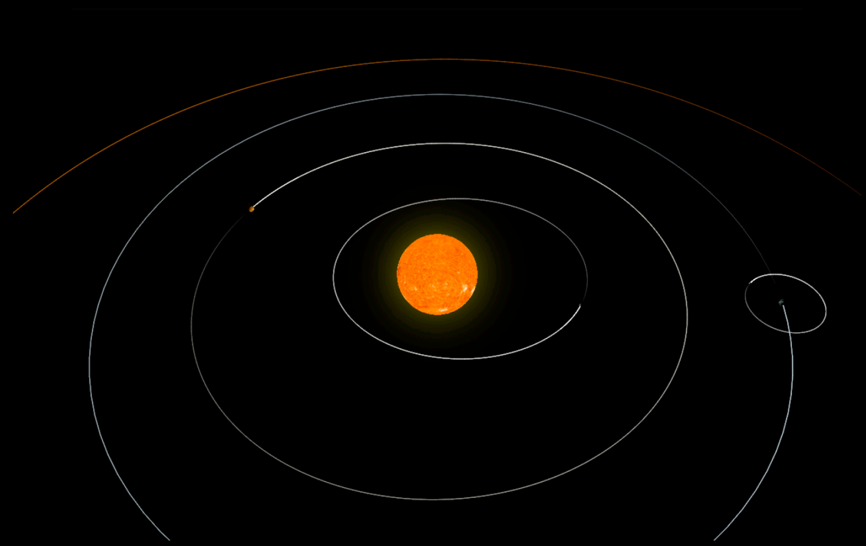
PREDICTIONX

Framework for Predictive Systems



https://openclipart.org/

#NON-RANDOM



Astrology

#RANDOMIZED

Ifa

#HUMAN

Egyptian "Bobble Head"

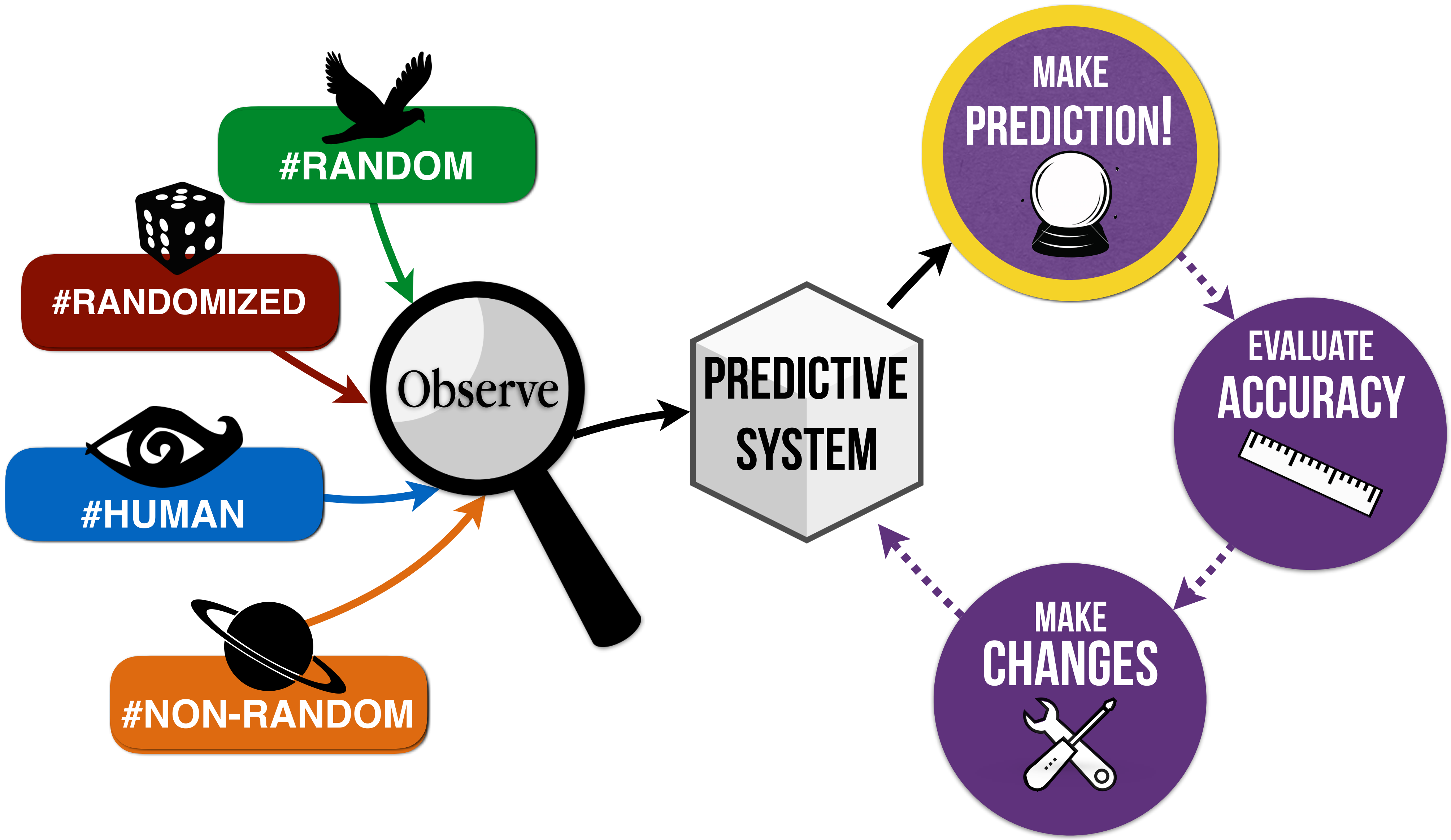
#RANDOM

Comets of Doom

#HUMAN

Ancient Egyptian Divination, featuring Prof. Peter der Manuelian (Harvard Semitic Museum)

Framework for Predictive Systems

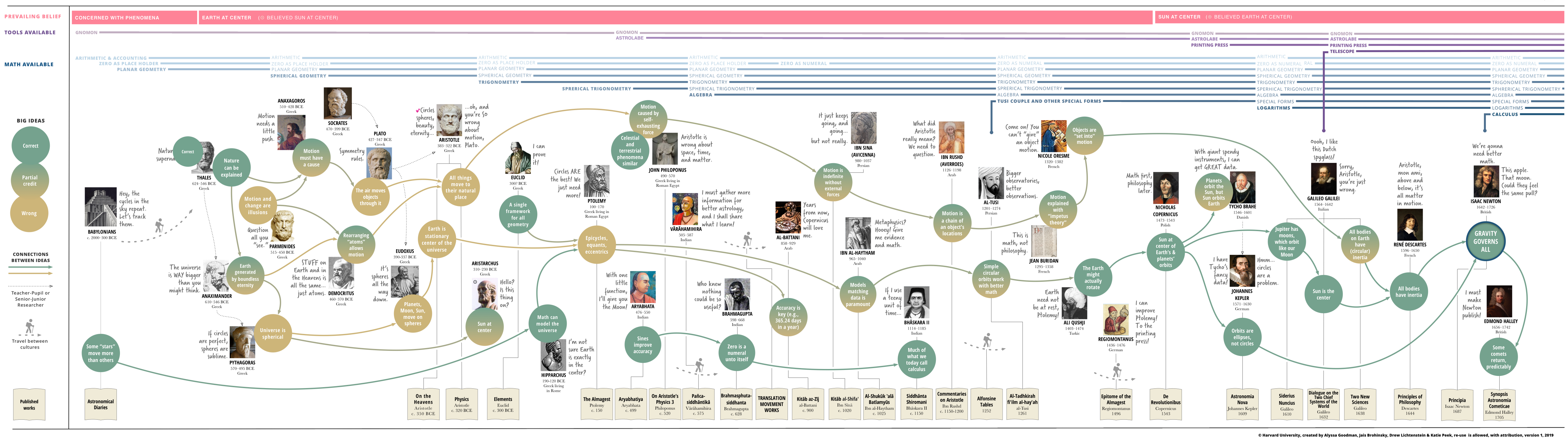


https://openclipart.org/

PREDICTIVE SYSTEMS

Phenomenon	Observation*	Data	Rule	Theory	Explanation	Prediction

The Path to Newton



or, Experiment

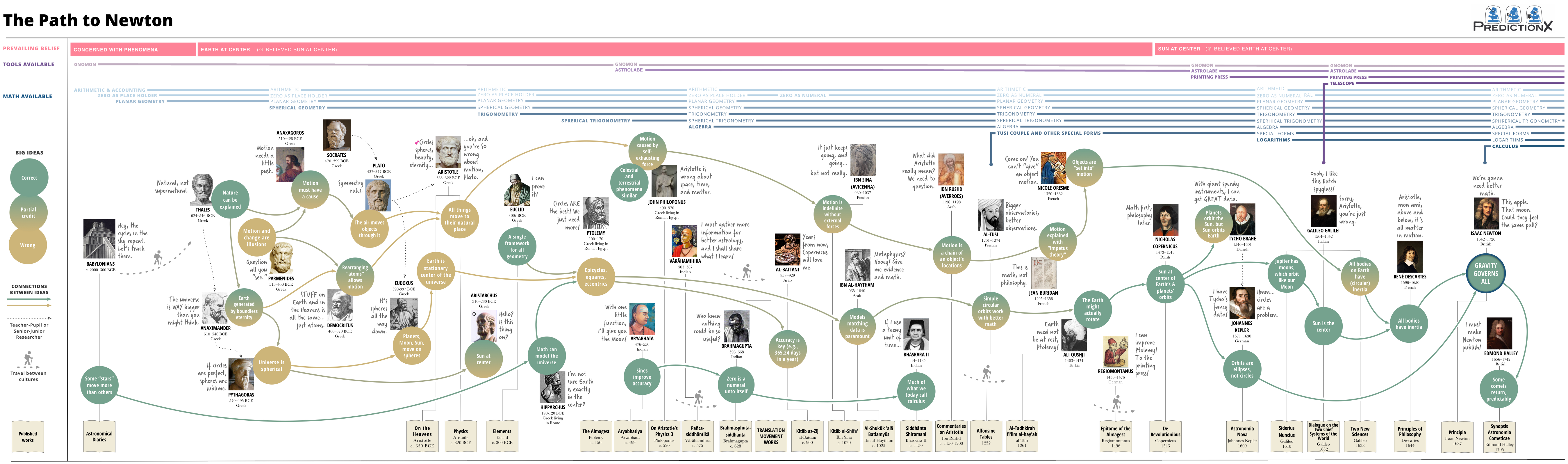
The Path to Newton

Alyssa Goodman
Jais Brohinsky
Drew Lichtenstein
& Katie Peek
on behalf of Harvard University

tinyurl.com/aas-path-to-newton

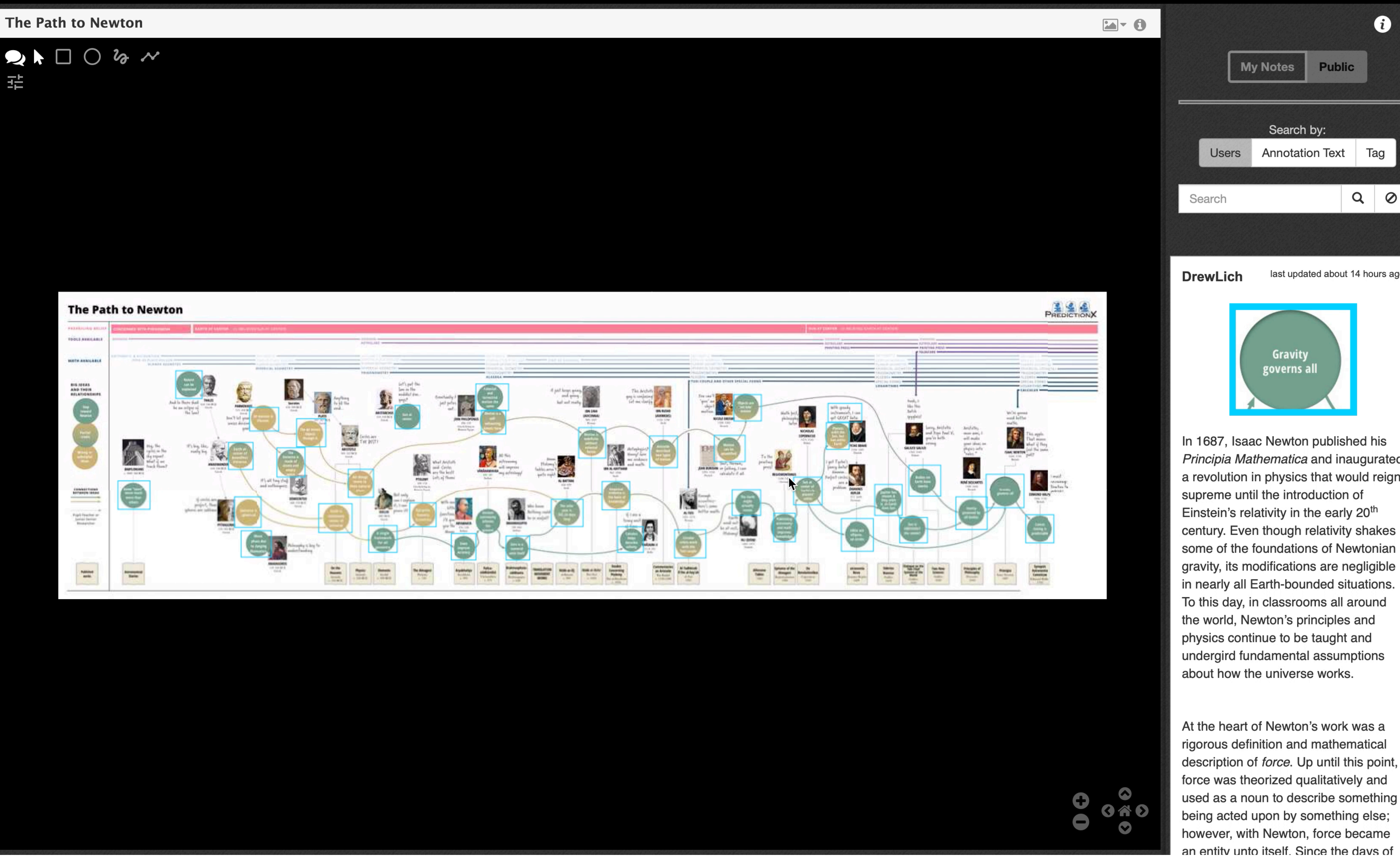
HarvardX

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN



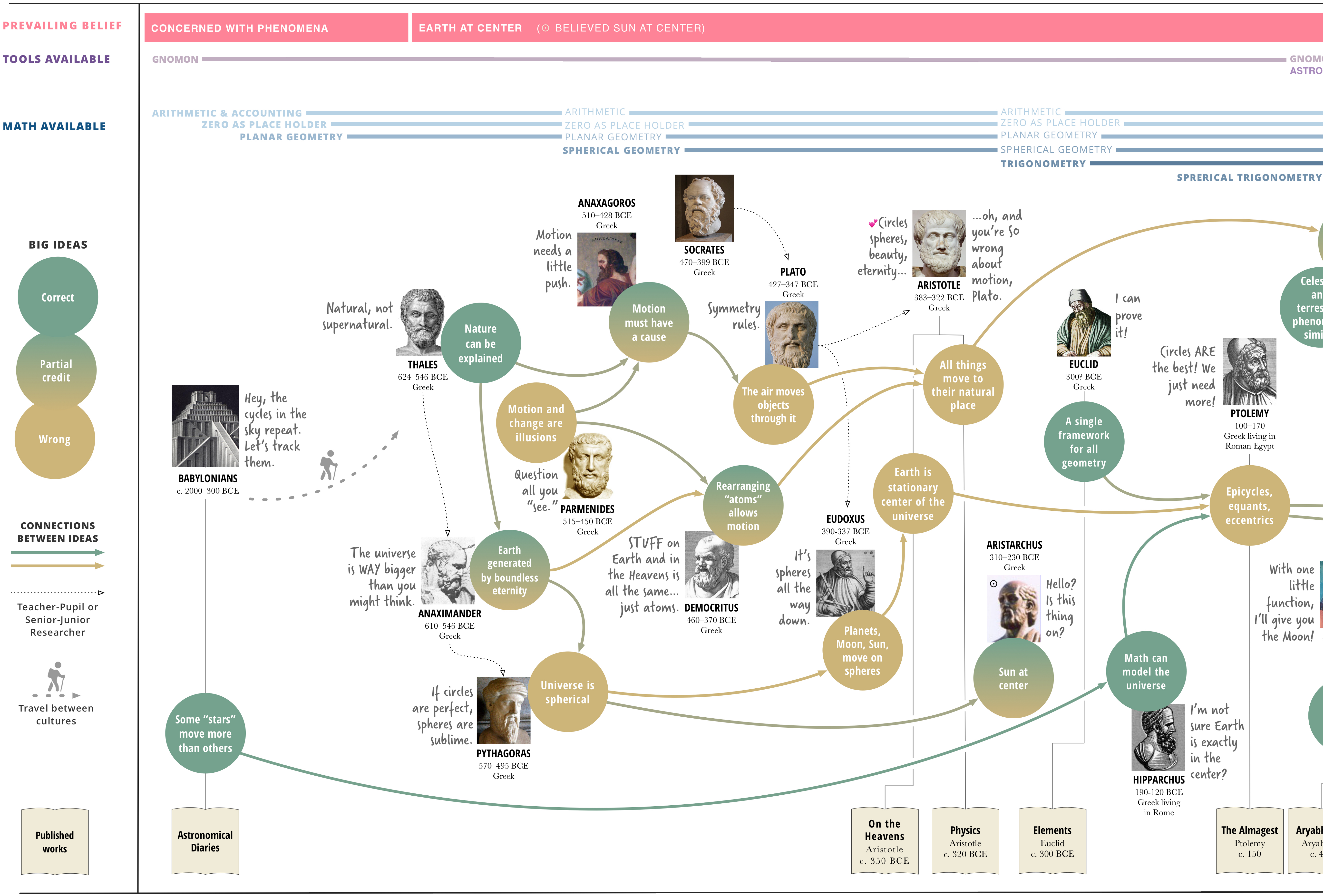
iPosterSessions
an aMuze! Interactive System

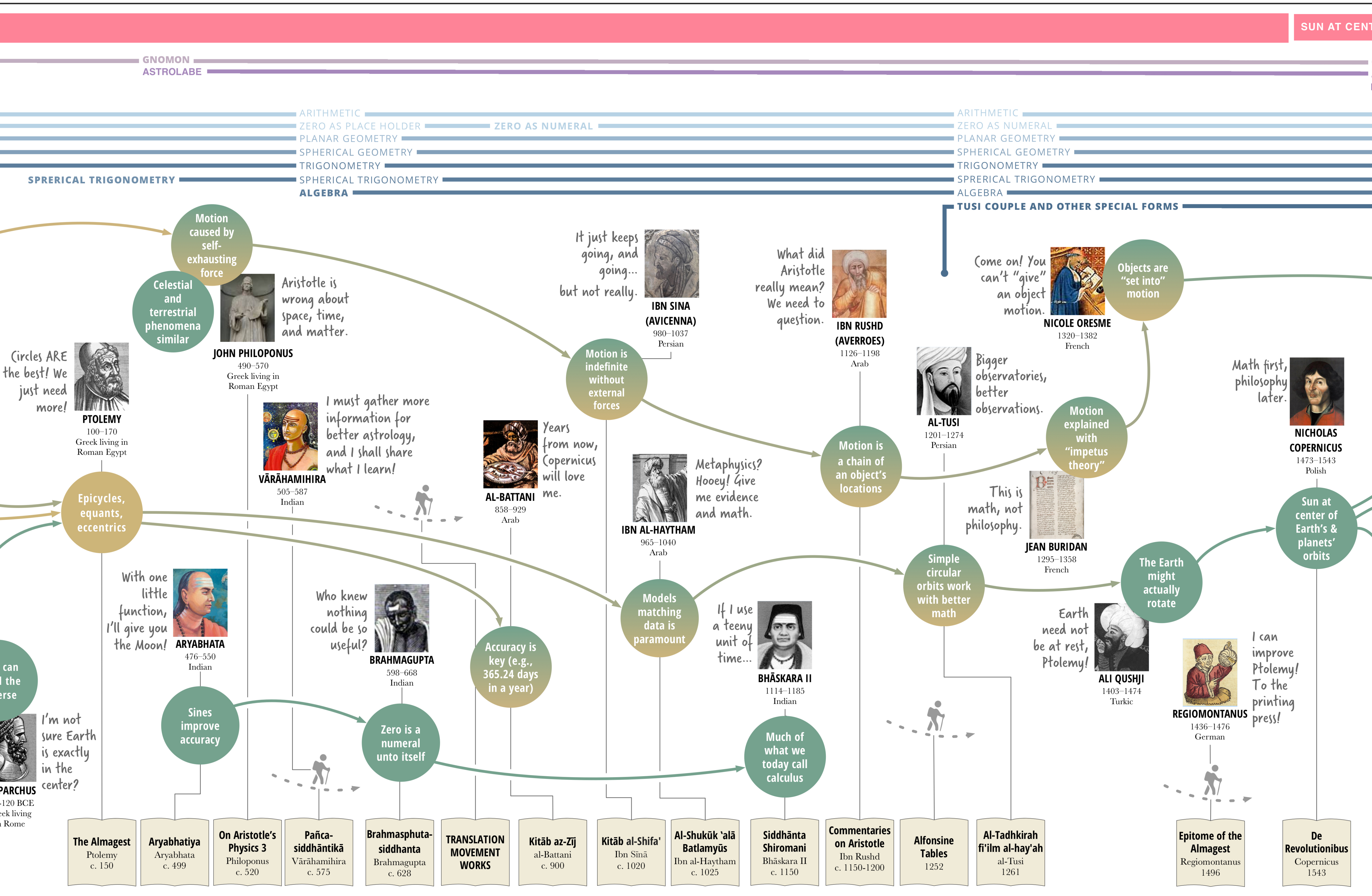
The Path online interacts with a narrative



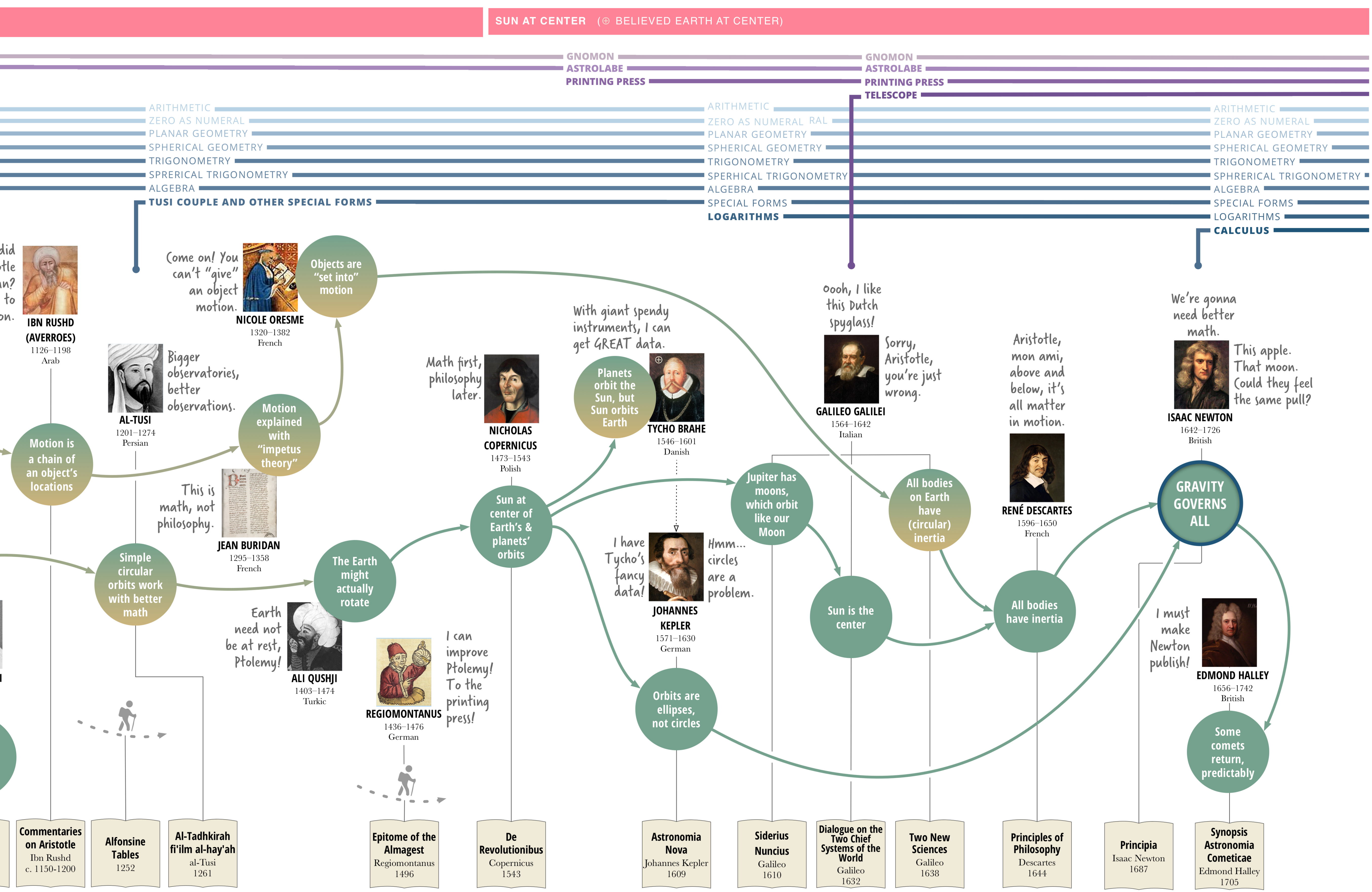
screencast courtesy of PredictionX course producer Drew Lichtenstein

The Path to Newton





SUN AT CENT
GNOMON
ASTROLABE
ARITHMETIC
ZERO AS PLACE HOLDER
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
SPHERICAL TRIGONOMETRY
ALGEBRA
ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS
Motion caused by self-exhausting force
Celestial and terrestrial phenomena similar
Aristotle is wrong about space, time, and matter.
JOHN PHILOPONUS
490–570
Greek living in Roman Egypt
Circles ARE the best! We just need more!
PTOLEMY
100–170
Greek living in Roman Egypt
Epicycles, equants, eccentrics
I must gather more information for better astrology, and I shall share what I learn!
VĀRĀHAMIHIRA
505–587
Indian
It just keeps going, and going... but not really.
IBN SINA (AVICENNA)
980–1037
Persian
Motion is indefinite without external forces
Years from now, Copernicus will love me.
AL-BATTANI
858–929
Arab
Metaphysics? Hooey! Give me evidence and math.
IBN AL-HAYTHAM
965–1040
Arab
What did Aristotle really mean? We need to question.
IBN RUSHD (AVERROES)
1126–1198
Arab
Motion is a chain of an object's locations
Bigger observatories, better observations.
AL-TUSI
1201–1274
Persian
Come on! You can't "give" an object motion.
NICOLE ORESME
1320–1382
French
Objects are "set into" motion
Motion explained with "impetus theory"
This is math, not philosophy.
JEAN BURIDAN
1295–1358
French
Math first, philosophy later.
NICHOLAS COPERNICUS
1473–1543
Polish
Sun at center of Earth's & planets' orbits
With one little function, I'll give you the Moon!
ARYABHATA
476–550
Indian
Who knew nothing could be so useful?
BRAHMAGUPTA
598–668
Indian
Accuracy is key (e.g., 365.24 days in a year)
Models matching data is paramount
If I use a teeny unit of time...
BHĀSKARA II
1114–1185
Indian
Simple circular orbits work with better math
Earth need not be at rest, Ptolemy!
ALI QUSHJI
1403–1474
Turkic
The Earth might actually rotate
I can improve Ptolemy! To the printing press!
REGIOMONTANUS
1436–1476
German
can
the
erse
I'm not sure Earth is exactly in the center?
PARCHUS
-120 BCE
eck living
Rome
Sines improve accuracy
Zero is a numeral unto itself
Much of what we today call calculus
The Almagest
Ptolemy
c. 150
Aryabhatiya
Aryabhata
c. 499
On Aristotle's Physics 3
Philoponus
c. 520
Pañca-siddhāntikā
Varāhamihira
c. 575
Brahmasphuta-siddhanta
Brahmagupta
c. 628
TRANSLATION MOVEMENT WORKS
Kitāb az-Zīj
al-Battani
c. 900
Kitāb al-Shifa'
Ibn Sīnā
c. 1020
Al-Shukūk 'alā Batlamyūs
Ibn al-Haytham
c. 1025
Siddhānta Shiromani
Bhāskara II
c. 1150
Commentaries on Aristotle
Ibn Rushd
c. 1150-1200
Alfonsine Tables
1252
Al-Tadhkirah fi'ilm al-hay'ah
al-Tusi
1261
Epitome of the Almagest
Regiomontanus
1496
De Revolutionibus
Copernicus
1543


SUN AT CENTER (⊕ BELIEVED EARTH AT CENTER)
GNOMON
ASTROLABE
PRINTING PRESS
TELESCOPE
ARITHMETIC
ZERO AS NUMERAL
PLANAR GEOMETRY
SPHERICAL GEOMETRY
TRIGONOMETRY
SPRERICAL TRIGONOMETRY
ALGEBRA
TUSI COUPLE AND OTHER SPECIAL FORMS
SPERHICAL TRIGONOMETRY
SPECIAL FORMS
LOGARITHMS
SPHRERICAL TRIGONOMETRY
CALCULUS
IBN RUSHD (AVERROES)
1126–1198
Arab
Come on! You can't "give" an object motion.
NICOLE ORESME
1320–1382
French
Objects are "set into" motion
AL-TUSI
1201–1274
Persian
Bigger observatories, better observations.
Motion explained with "impetus theory"
Motion is a chain of an object's locations
This is math, not philosophy.
JEAN BURIDAN
1295–1358
French
Simple circular orbits work with better math
Earth need not be at rest, Ptolemy!
ALI QUSHJI
1403–1474
Turkic
The Earth might actually rotate
Math first, philosophy later.
NICHOLAS COPERNICUS
1473–1543
Polish
Sun at center of Earth's & planets' orbits
I can improve Ptolemy! To the printing press!
REGIOMONTANUS
1436–1476
German
With giant spendy instruments, I can get GREAT data.
Planets orbit the Sun, but Sun orbits Earth
TYCHO BRAHE
1546–1601
Danish
I have Tycho's fancy data!
Hmm... circles are a problem.
JOHANNES KEPLER
1571–1630
German
Orbits are ellipses, not circles
Jupiter has moons, which orbit like our Moon
Oooh, I like this Dutch spyglass!
Sorry, Aristotle, you're just wrong.
GALILEO GALILEI
1564–1642
Italian
Sun is the center
All bodies on Earth have (circular) inertia
Aristotle, mon ami, above and below, it's all matter in motion.
RENÉ DESCARTES
1596–1650
French
All bodies have inertia
We're gonna need better math.
This apple. That moon. Could they feel the same pull?
ISAAC NEWTON
1642–1726
British
GRAVITY GOVERNS ALL
I must make Newton publish!
EDMOND HALLEY
1656–1742
British
Some comets return, predictably
Commentaries on Aristotle
Ibn Rushd
c. 1150-1200
Alfonsine Tables
1252
Al-Tadhkirah fi'ilm al-hay'ah
al-Tusi
1261
Epitome of the Almagest
Regiomontanus
1496
De Revolutionibus
Copernicus
1543
Astronomia Nova
Johannes Kepler
1609
Siderius Nuncius
Galileo
1610
Dialogue on the Two Chief Systems of the World
Galileo
1632
Two New Sciences
Galileo
1638
Principles of Philosophy
Descartes
1644
Principia
Isaac Newton
1687
Synopsis Astronomia Cometicae
Edmond Halley
1705

PREDICTIONX

predictionx.org

PREDICTIONX: THE PAST & PRESENT OF THE FUTURE

TOOLS

Framework for Predictive Systems (edX)

Framework for Study Design

Understanding Uncertainty

Timelines

Why predict?

Omens, Oracles & Prophecies

(edX)

Mesopotamian Haruspicy

Egyptian Priests

Yoruba Ifa

Tarot

Roman Augury

Casting Lots

The Diviner's Guide

Chinese Oracle Bones

Greek Astronomy

Oracle of Delphi

Turkish Tasseography

Astrology

Aztec Rituals

Maya Spacetime

Comets of Doom

cross-cultural conversations

THE RISE OF THEORY

Islamic Science

The Royal Society

John Snow & Cholera (edX)

Cholera Map

The Path to Newton

Lost without Longitude (Navigation) (edX)

Indian Mathematics

Tools of the Navigator (edX)

Help, I'm Lost! (edX)

MODERN SIMULATION

Health

Epidemiology

Personal Genomics

Earth

Earthquakes

Climate Change

Tent Tarot (edX)

Wealth

Personal Finance

World Economy

Space

Futures of our Universe

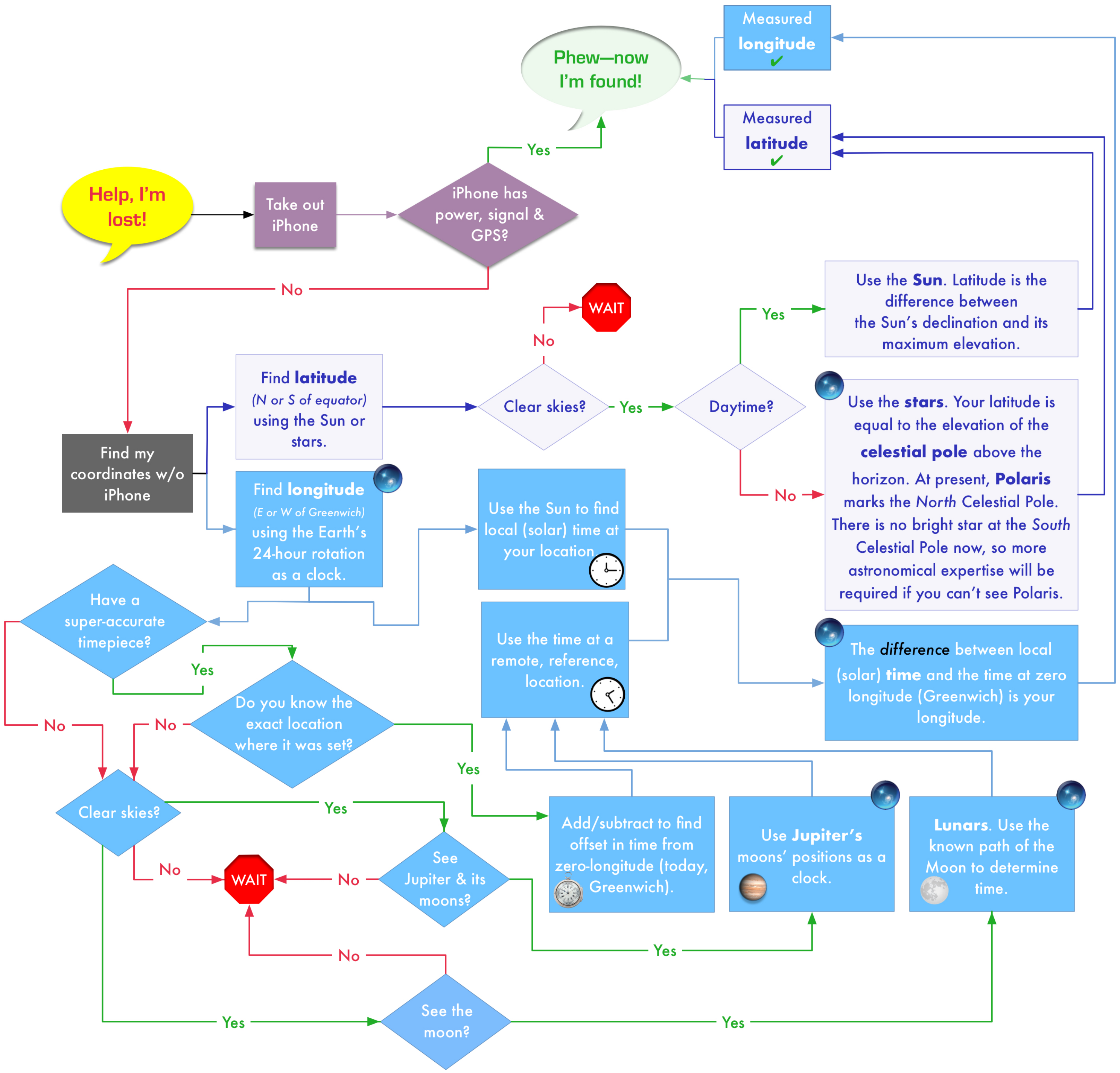
The Future of the Future

Artificial Intelligence

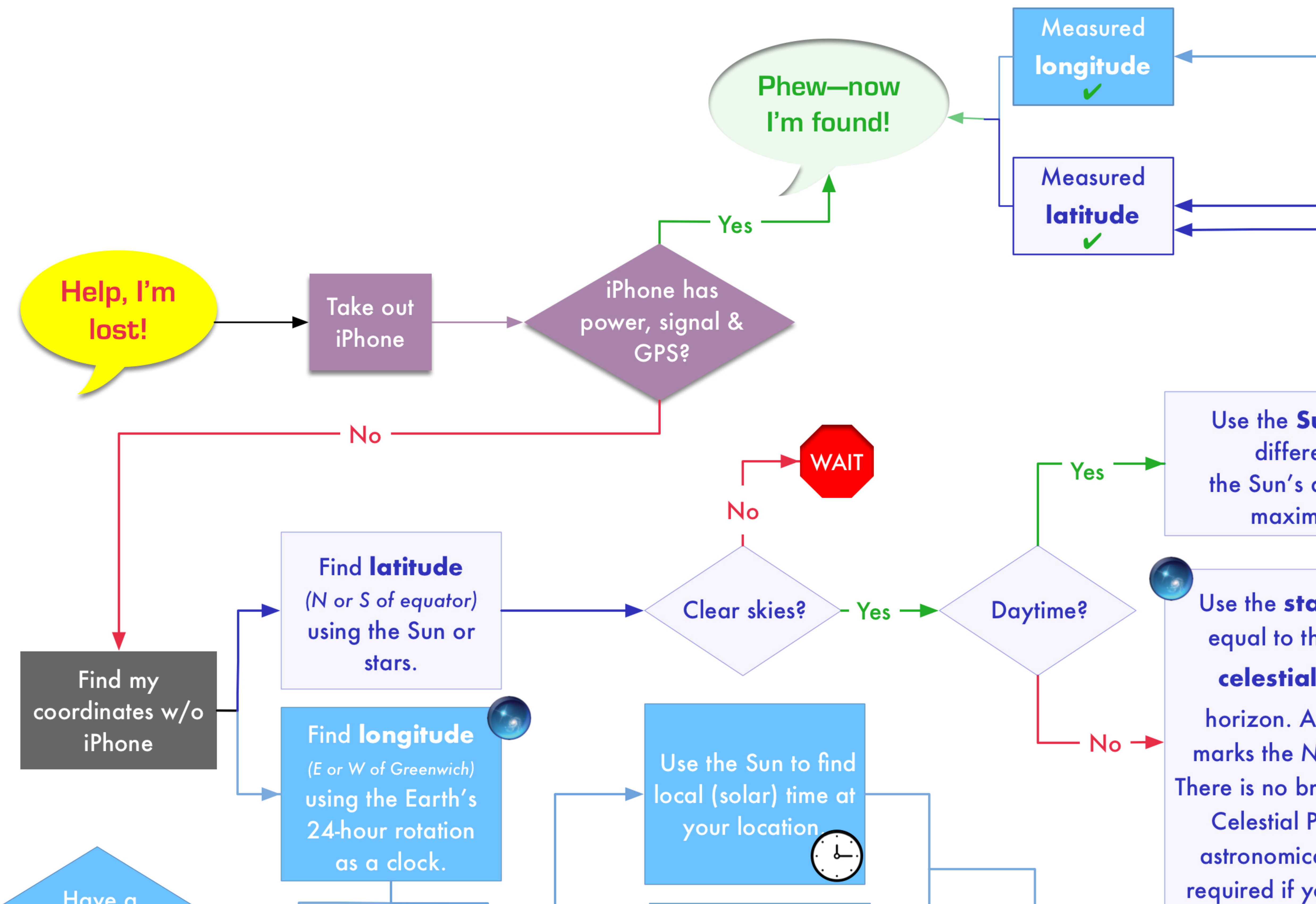
Derek's Day

Finished | Coming Soon | Planned | Interactive Resource | ▷ video(s) | edX link to edX (often contains videos + interactives, not marked separately here)

“Lost without Longitude”



“Lost without Longitude”



Earth as a Clock

The Celestial Sphere

Jupiter’s Moons

Latitude & Longitude

Lunars on the Sky

Why Lunars are Hard

PREDICTIONX

predictionx.org

PredictionX: The Past & Present of the Future

Tools

- Framework for Predictive Systems (edX)
- Framework for Study Design
- Understanding Uncertainty
- Timelines
- Why predict?

Omens, Oracles & Prophecies

(edX)

- Mesopotamian Haruspicy
- Egyptian Priests
- Yoruba Ifa
- Tarot
- Roman Augury
- Casting Lots
- **The Diviner's Guide**
- Chinese Oracle Bones
- *Greek Astronomy*
- Oracle of Delphi
- Turkish Tasseography
- Astrology
- Aztec Rituals
- Maya Spacetime
- Comets of Doom
- **cross-cultural conversations**

The Rise of Theory

- Islamic Science
- The Royal Society
- John Snow & Cholera (edX)
- Cholera Map
- The Path to Newton
- Lost without Longitude (Navigation) (edX)
- Indian Mathematics
- Tools of the Navigator (edX)
- Help, I'm Lost! (edX)

MODERN SIMULATION

Health

- Epidemiology
- Personal Genomics

Earth

- Earthquakes
- Climate Change
- Tent Tarot (edX)

Wealth

- Personal Finance
- World Economy

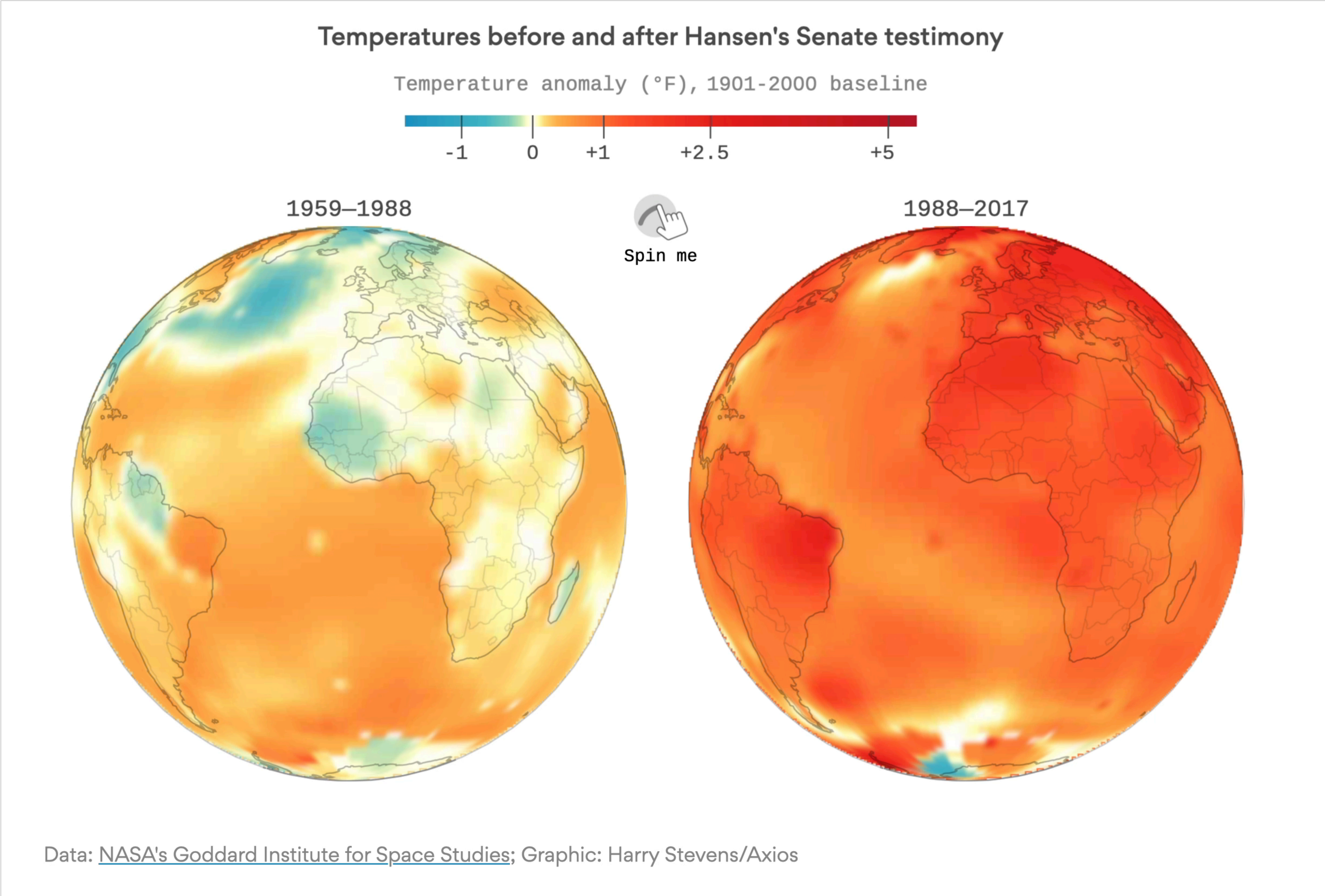
Space

- Futures of our Universe

The Future of the Future

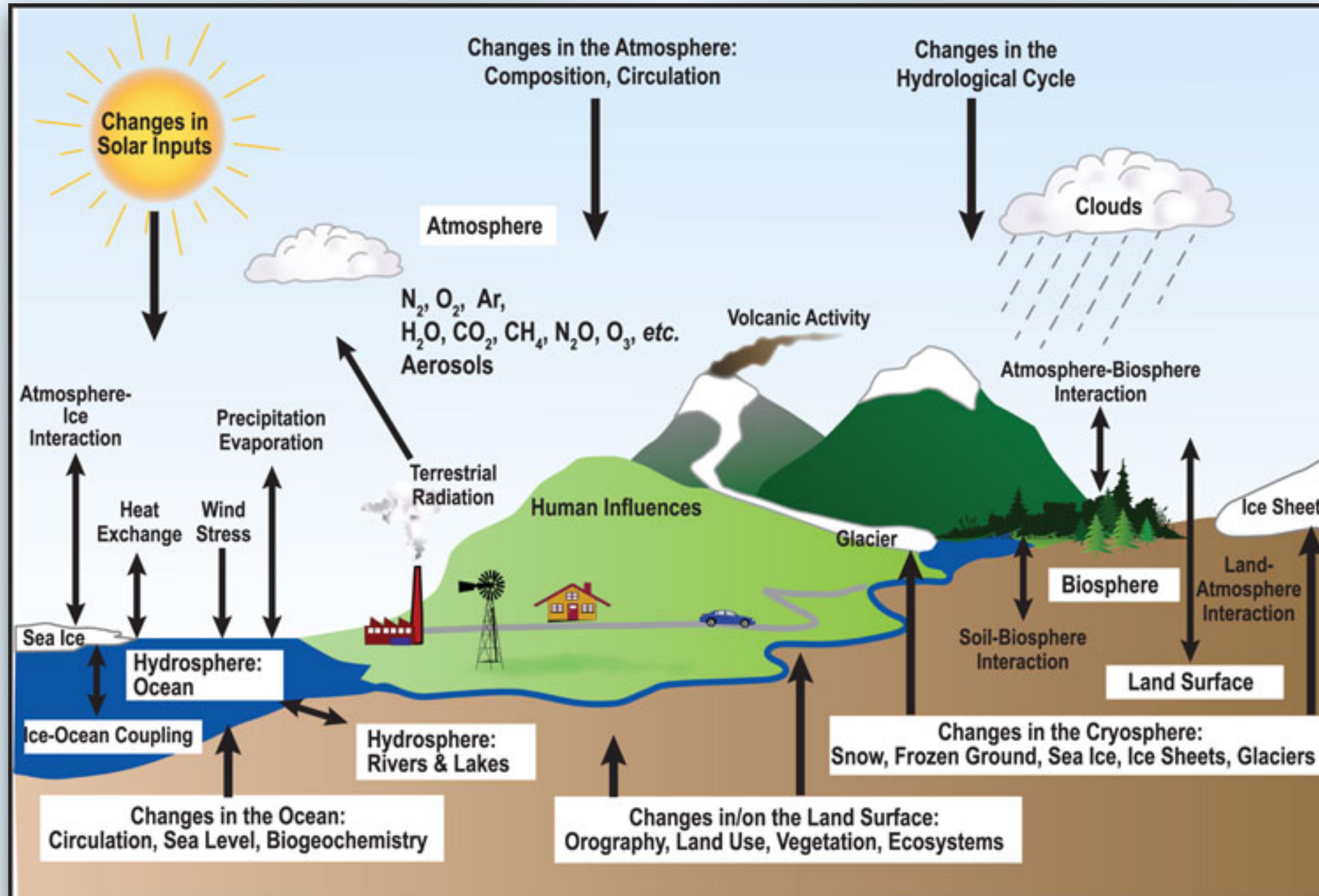
- Artificial Intelligence
- Derek's Day

Finished | Coming Soon | Planned | Interactive Resource | ▷ video(s) | edX link to edX (often contains videos + interactives, not marked separately here)

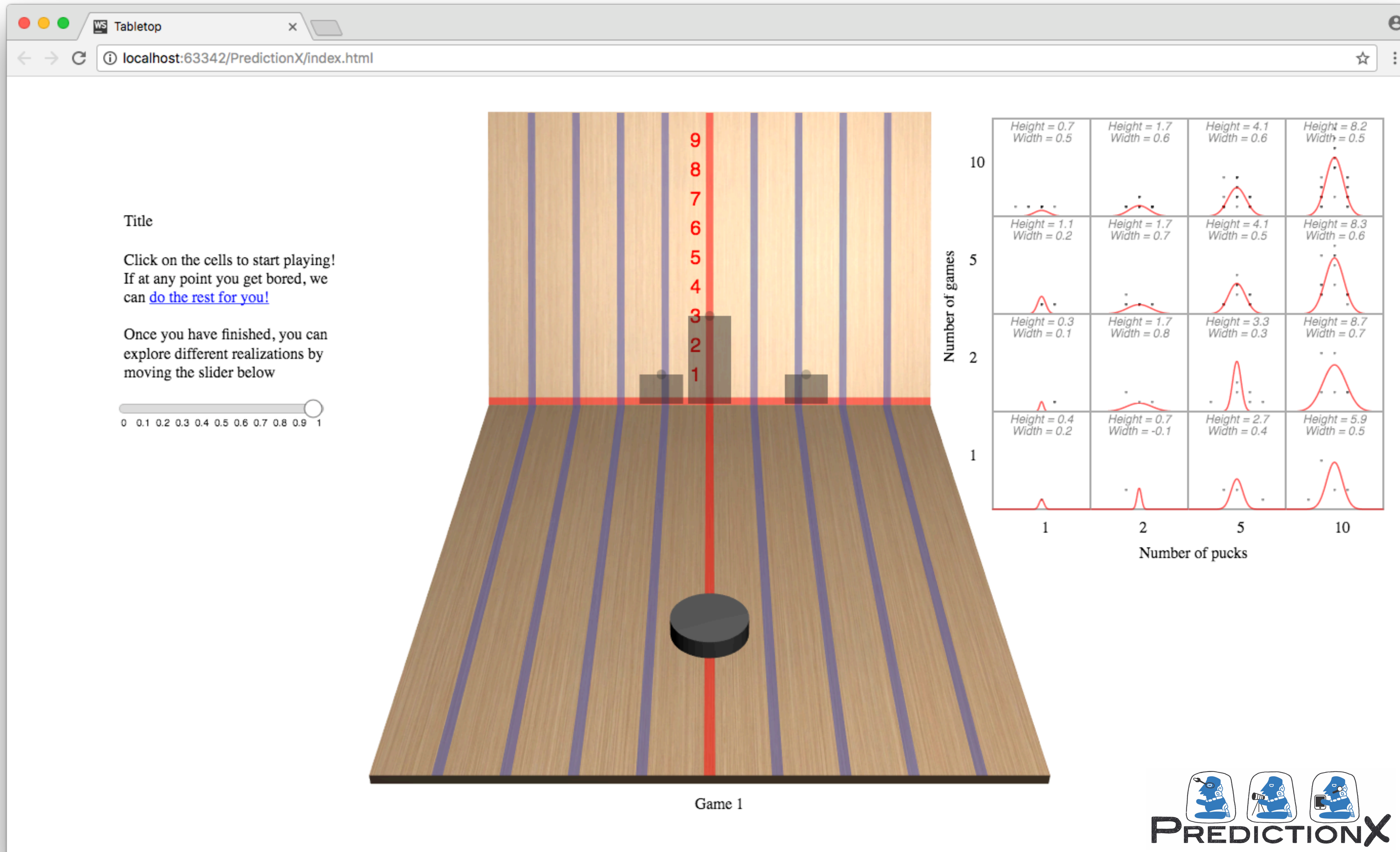


https://www.axios.com/how-much-earth-has-warmed-since-hansen-testified-b6f8fdb4-484e-477f-b8b6-6ee320994dc0.html

MODERN SIMULATION

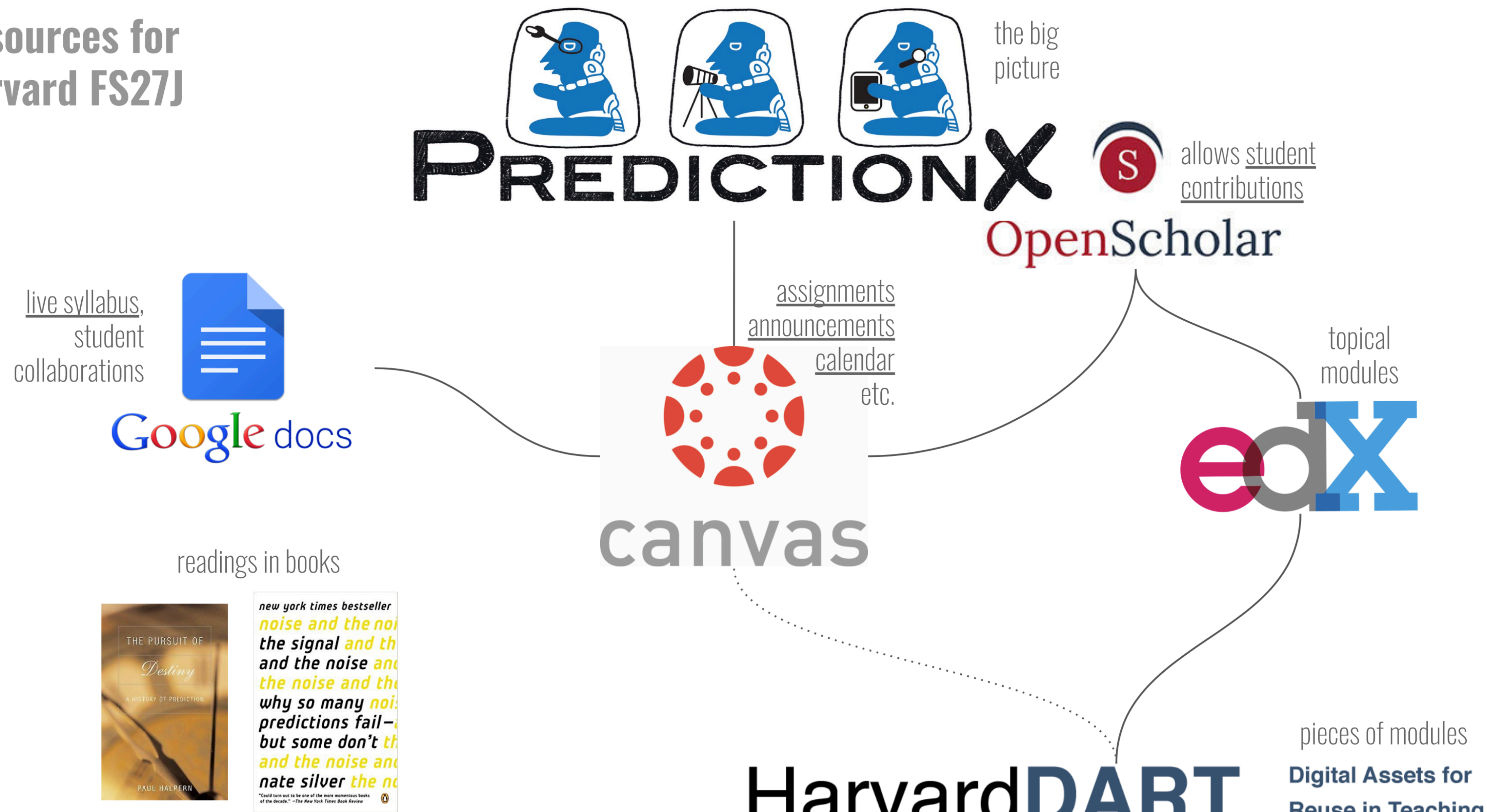


"Scaffolding" MODERN SIMULATION



How technologies can combined at Harvard now (from Freshman Seminar 27J)

Resources for Harvard FS27J



https://canvas.harvard.edu/courses/43639

PredictionX Tech

Established	New	Distribution
esri ArcGIS®	Take A Sweater	edX
OmniGraffle	HarvardX video annotation tool	YouTube CHANNEL
WorldWide Telescope	The TIMELINE CONSORTIUM	HarvardDART

V. 2017

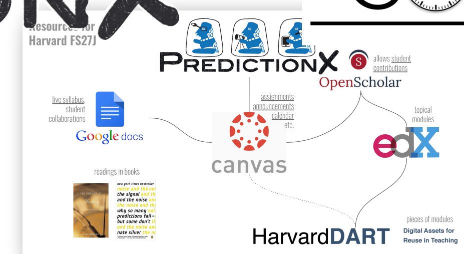
2008

2012

2013

PredictionX

2015-

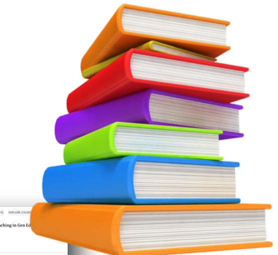


2015-18

The TIMELINE CONSORTIUM

2016-

2020

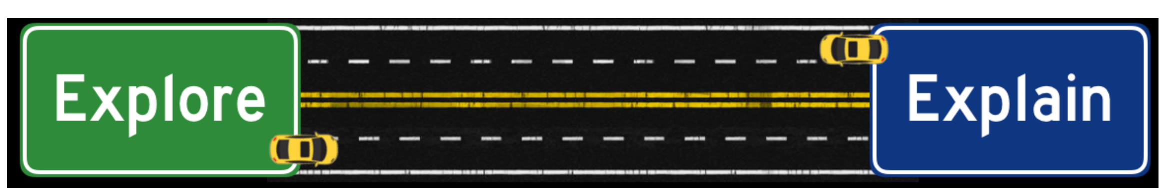


2020-?

(Paths to) today.

1 Viz

2017-



2018

2018

2019

Coming to Harvard GenEd in 2020 (ask Jais!)

CURRENT GEN ED PROGRAM (THROUGH SPRING 2019) EXPLORE COURSES BY CATEGORY & TERM

HARVARD COLLEGE
THE NEW PROGRAM IN GENERAL EDUCATION

Courses Requirements Teaching in Gen Ed Contact

EXPLORE COURSES BY

Category

Aesthetics & Culture (36)
Ethics & Civics (32)
Science & Technology in Society (30)
Histories, Societies, Individuals (47)

Semester

Fall 2019 (40)
Spring 2020 (42)
2019-2020 (Semester TBD) (2)
Fall 2020 (16)
Spring 2021 (4)
2020-2021 (Semester TBD) (18)
Coming Soon (5)

HOME / COURSES /

Prediction: The Past and Present of the Future (Gen Ed 1112)

Semester: Spring
Offered: 2020

SCIENCE & TECHNOLOGY IN SOCIETY

Alyssa Goodman

Human beings are the only creatures in the animal kingdom properly defined as worriers. We are the only ones who expend tremendous amounts of time, energy, and resources trying (sometimes obsessively) to understand our futures before they happen. While the innate ability of individual people to predict has not changed much in the past few millennia, developments in mathematical and conceptual models have inordinately improved predictive systems. These systems have integrated comparisons to past results and quantified how "certain" we can be about various aspects of the future -- processes that were, in many cases, inconceivable at one point in the past. This course is a coordinated investigation of the history and future of prediction, beginning with Ancient Mesopotamians reading signs in sheep entrails and ending with modern computer simulations for climate, health, wealth, and the fate of our Universe. In this class, you will design your own predictive systems to critically engage with assumptions about how the world works and situate your explorations in a study of how motivations and techniques for divining the future have changed–and not changed–throughout human history.

We					5	6	7
Top				eory	Empirical vs. Predictive	Navigation is Prediction	Data Driven Decisions
Cas				wton	Copernicus / Newton	Lost w/o Longitude	John Snow
Content Concept				cient and t the world of about the ons evolved tive systems wly! (against lution)	Smaller picture: - Truly predictive system (opposed to empirically derived) - Individual contributions to history of ideas - Importance of specific ideas and theories along Path - Importance of specific instruments to progress along the Path and correlations to ideas and theories - Extrapolation to future (eg genome sequences)	- Particular instance of predictive theory (idea of lunars) but not enough data + precision in instruments - UNCERTAINTY - Interaction between development of technology and uncertainty - How models (e.g. celestial sphere) can be 'true enough' to make meaningful predictions	Bridge between Rise of Theory and Modern Simulation - Advent of modern epidemiology - Use of visualization to make predictions about health/disease - Visualization as representation/ exemplification
Possible Guests Panels or presentations in the evenings?		Piotr Steinkeller, Irving Finkel (?)	Choose from: Peter Manuelian, Emma Dench, Jacob Olupuna, David Carrasco, Laura Nasrallah	Owen Gingerich, Ahmad Ragab, Hannah Marcus, Sara Schechner	Owen Gingerich, Ahmad Ragab, Hannah Marcus, Sara Schechner (comets)	John Huth, Dava Sobel, Phil Sadler	Immaculata DeVivo, Peter Kraft, Susan Murphy
Models and Visualizations	Prediction Framework	Timeline tool introduction	Timeline tool (show offset parallels in cultures)	**Universe Systems:** (Aristotle, Ptolemy, Copernicus, Brahe) **Theories of Motion:** (Aristotle, Philoponus, Impetus, Galileo, Descartes, Newton)	**Universe Systems:** (Aristotle, Ptolemy, Copernicus, Brahe) **Theories of Motion:** (Aristotle, Philoponus, Impetus, Galileo, Descartes, Newton)	Geographic coordinate system, equatorial coordinate system, celestial sphere (armillary sphere mobile app?), google maps	John Snow's map (https://www1.udel.edu/johnmack/frec682/cholera/snow_map.png)
Activities	List of questions (e.g. how many countries are represented by Harvard's student population) -- for each question, create the *narrowest* number range that you are 98% sure encapsulates the correct answer (specifically *not* 100%). Pollall answers ... discuss with neighbors ... show actual ... discuss with neighbors ... discuss with class	Learn to use the framework to evaluate different predictive systems	Arrange a number of the ancient systems to be done in class? Students move through the different systems in small groups and experience them? (Ancient Systems Expo!)	Intro Rainbow Diagram?	PtN Expo - each student has read article about person's contribution (plus short bio?) and acts as representative for the idea ... each student has a version of path with blank bubbles, needs to mingle and meet others, get ideas, fill it out		Pandemic Simulation -- HKS Mexican Flu or Zombie
Section				Earth / Sun and Arrow Exercise: What is today? What does this mean? The Earth revolves around the Sun ... how do you know? Explain motion of toy bow and arrow without words like 'gravity,' 'force,' 'acceleration,' etc.	PtN Expo continued -- sections work to verify each other's findings, then as a group create a full PtN then decide the color code of 'correctness.'		Debrief Simulation
Assignments (for following week)	1-2 paragraph response: What is prediction? How do you go about making a prediction (what factors, how do you weigh, etc) How good are humans at predicting?	Choose a divination system from Diviner's Guide to study in more depth, become expert on one system (an ancient system expo ala PtN?)	Online group projects, merge, in person (wordpress, google slides, etc)	Choose a person from the path to research ... be able to speak from their perspective and explain their contribution to the Path to Newton for PtN Expo.	Share the different Paths created (wordpress, google slides, etc) and curate an online exhibition of them all	Map of their day (comparison with google map chart) (difference between machine learning and intuitive human understanding)	Student flu, stomach bug, cold, etc. maps? (2 weeks?) OR Combine with last to make an epidemiological (ish) map of something in their lives
Journal (for following week)	Log: How often/when/where do you use it in your life? Begin recording the different predictions that you make on a daily basis -- what systems to you use to make them?	Log: continue recording day-to-day predictions and systems Observations/Predictions: choose between Moon, Sports Team, Stock, Television shows ... Follow your chosen subject for two weeks. Every day, record observations (e.g. rise/set/shape; win/loss; pricing) and make predictions about the next day (or game, for sports). Justify and explain your prediction. Discuss previous predictions -- what went well/poorly, what can you change in	Log: continue Observations/Predictions: continue Questions: what type of input are you engaging? how are your predictions evolving?	Log: continue Observations/Predictions: switch subject, or continue with what you have Questions: at end of two weeks, put your predictions and your findings in conversation through visual representation	Log: continue Observations/Predictions: continue Questions: if you've changed observations, discuss differences between the phenomena. if you've continued, how have your observations and predictions changed? what new questions are coming up?	Log: continue Observations/Predictions: switch subject, or continue with what you have Questions: at end of two weeks, put your predictions and your findings in conversation through visual representation	Log: continue Observations/Predictions: continue Questions: if you've changed observations, discuss differences between the phenomena. if you've continued, how have your observations and predictions changed? what new questions are coming up?
Possible readings/ videos/ etc (due on that day)		- Pursuit of Destiny Ch 1? - Thematic essays	- edX video of your system - Article specific to your system	- Ch from Shapin: The Scientific Revolution or - Dear: Revolutionizing the Sciences	- Primary document specific to your person from PtN - Something on Newton to understand how to choose what is important about their individual's contribution	edX course	edX course

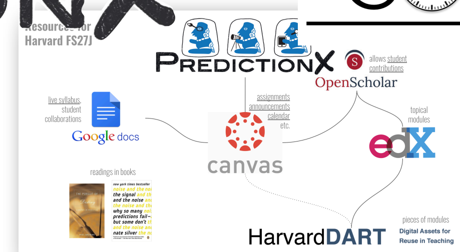
We	8	9	10	11	12	13
Top	Modern Approaches to Prediction	Climate	Money	Machines	Space	The Future of the Future
Cas	Weather	Climate Change Simulation	Personal/ Global Finance	AI / Machine Learning	Are we alone? ET Life	Integration of everything
Content Concept	- Is the framework missing anything? - How does the framework apply in modern world - Time/ Spatial resolution - Uncertainty (estimation) - Human/instrumental biases - Physical/chemical processes - Bayesian statistics - Future w/ theory and future w/o theory	- What does uncertainty in weather forecasting show about climate change? - What contributes to people's/ organizations' decisions regarding long term predictions like climate change? - How are climate simulations created and what do they show?	- Connection between climate and finance - Complexity of social systems/ complexity theory - Can economics be considered science?	- How are computers used to make predictions? - What is machine learning? - What is intelligence and can computers have it?	- Simulation on timescales we can't observe - Are we alone? Drake Equation (astronomy => astrophysics => exoplanets as example of technologies influencing uncertainty influencing prediction parameters) - Cosmic Evolution	- Student conceptions - What is Prediction? - Different predictive systems through history
Possible Guests Panels or presentations in the evenings?		Choose from: Brendan Meade, Jerry Mitrovica, Dan Kamen	Rebecca Henderson, David Laibson	Ben Shneiderman, David Parkes	Avi Loeb, Paul Horowitz, Martin Elvis, Blakesley Burkhart	George Church, others who couldn't make it before
Models and Visualizations	Take a sweater, google maps, Framework				WWT	
Activities	- Review/ Revision of Framework - Examples from first week... how are you using prediction?		Trading game: (https://www.economicsnetwork.ac.uk/showcase/sloman_game) or **HLS Negotiation Oil Pricing Game** (https://www.pon.harvard.edu/shop/oil-pricing-exercise-3/)	Simulated Turing Test?	Simulation -- Planetary Defense asteroid simulation (w/ Alissa Haddaji) or A Spaceship Appears (Jais)	Prediction Fair! Find space for exposition in which students present 'posters' on their predictive systems
Section	Speed dating Final Prediction ideas		Debrief Oil Pricing		Debrief Simulation	Themed sections
Assignments (for following week)	Personal Derek's Day ... how do you use Bayesian forecasting in your own life?	Land Science Online Game: https://lem.epistemic-games.org/	Land Science Online Game: https://lem.epistemic-games.org/	Work on Project?	Work on Project? Create WWT tour?	Short reflection comparing initial assignment to current thinking and how this has/hasn't changed
Journal (for following week)	Log: continue Observations/Predictions: choose a phenomenon that you want to follow for the remainder of the semester and devise a system for predicting about it Questions: at end of two weeks, put your predictions and your findings in conversation through visual representation	Log: continue Observations/Predictions: final Weekly update	Log: continue Observations/Predictions: final Weekly update	Log: continue Observations/Predictions: final Weekly update	Log: continue Observations/Predictions: final Weekly update	PREDICTION FAIR
Possible readings/ videos/ etc (due on that day)	Taleb - Black Swan Ch 3 (types of uncertainty) Silver - Introduction	Silver - Signal/Noise Ch 12 (climate) Kahan et al - The polarizing impact of science literacy and numeracy on perceived climate change risks	Popper - Poverty of Historicism? Hayek - Pretence of Knowledge? Silver - Signal/Noise Ch 1, 8 Less and Less and Less Wrong	Silver - Signal/Noise Intro, Ch 9 (rage against machines)		

2012

2008

2013

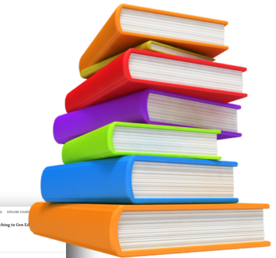
2015-



2015-18

2016-

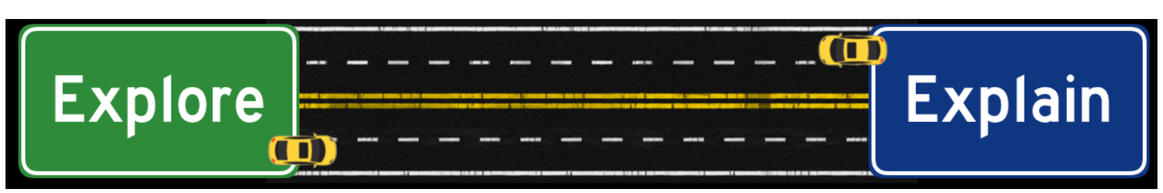
2020



2020-?

(Paths to) today.

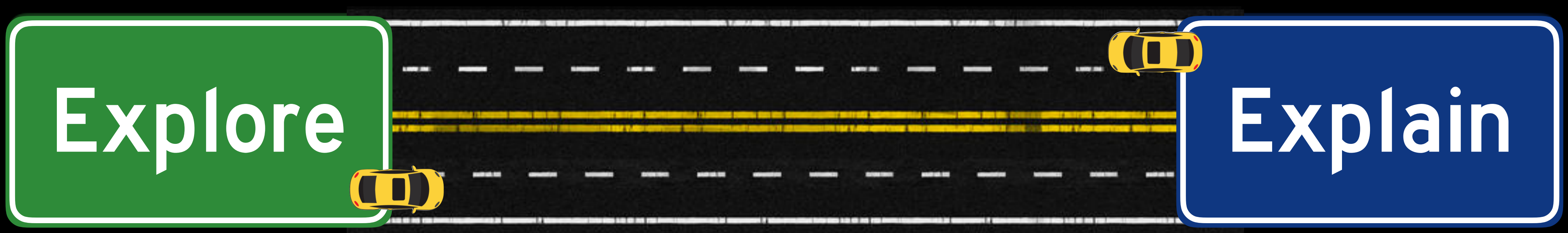
2017-



2018

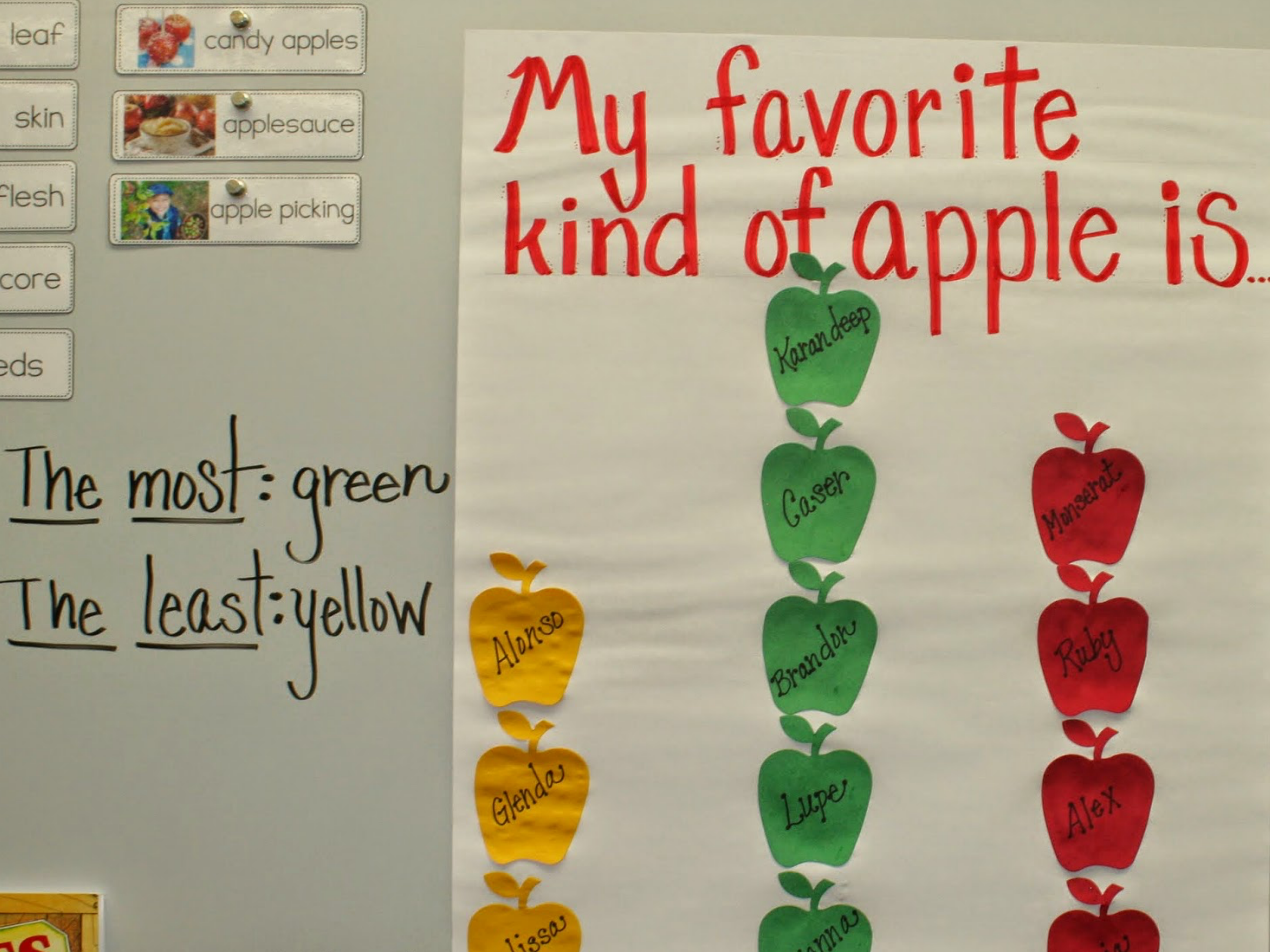
2018

2019


Explore
Explain

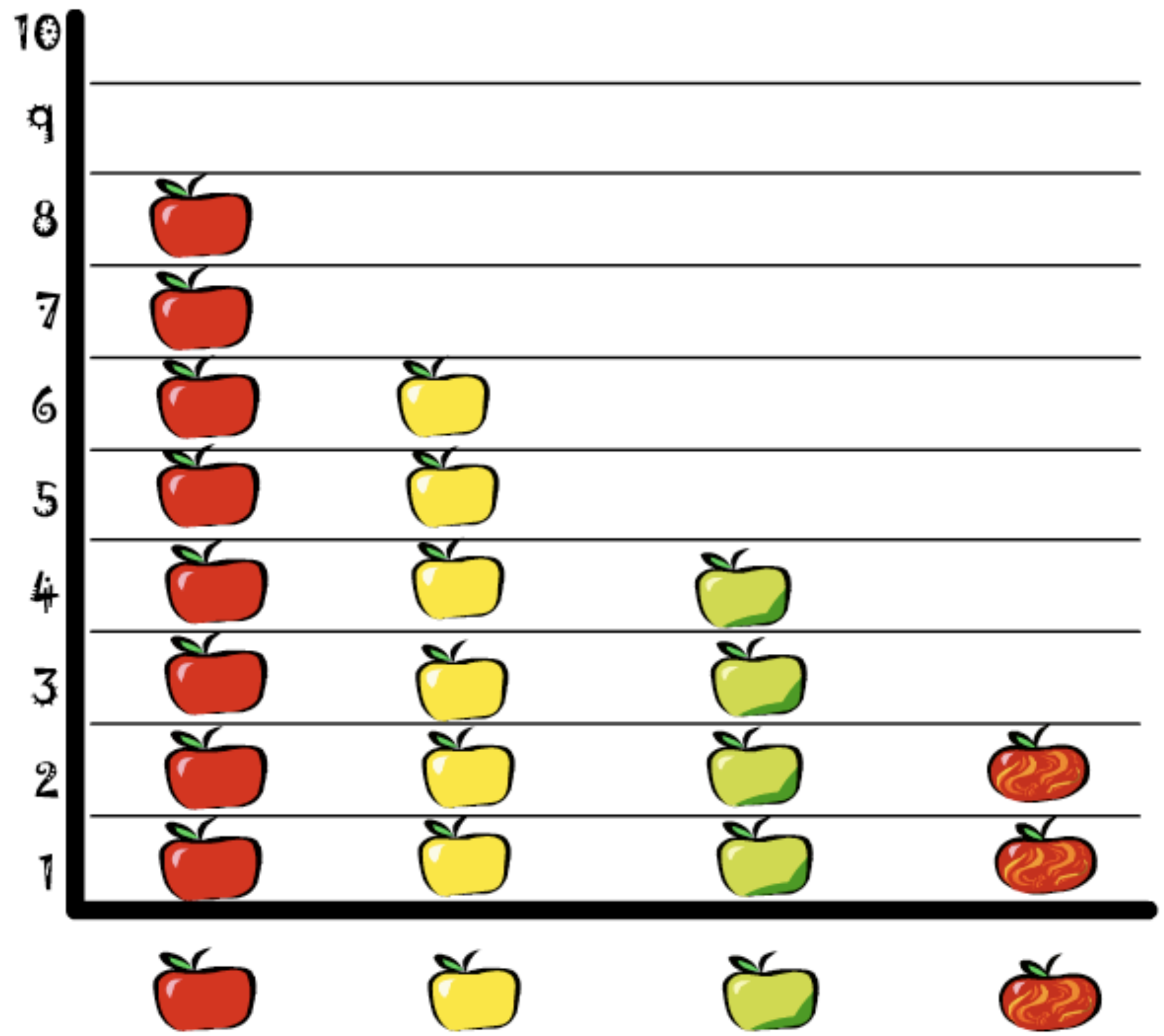
Which apple did you like the best?

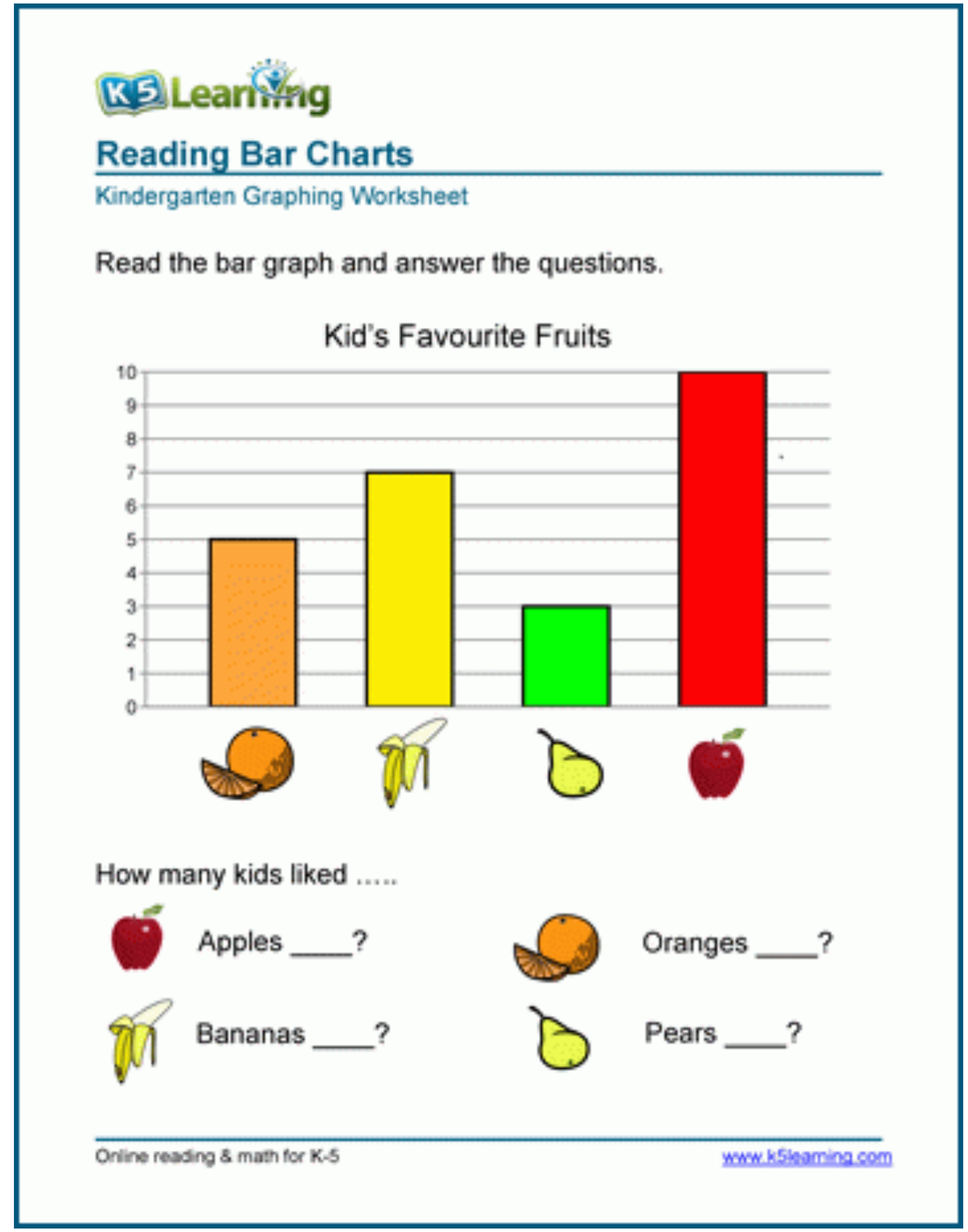
Granny Smith Apples	Golden Apples	Red Delicious Apples
1. Jaiden	1. Jimena	1. Gurkirat
2. Victoria	2. Paige	2. Alex
3. Nahira	3. Alan	3. Steve
4. Arely		4. Isabela
5. Anahi		5. Andrea
6. Julian		6. Neha
7. Jose		7. Kristian
8. Giovanni		8. Ms. Alma
9. Eliazar		9. Ms. Maria


leaf
candy apples
skin
applesauce
flesh
apple picking
core
My favorite kind of apple is...
The most: green
The least: yellow
Karandeep
Caser
Monserat
Alonso
Brandon
Ruby
Glenda
Lupe
Alex

Our Favorite Apples

Directions: Make a graph by dragging the apples:





K5 Learning

Reading Bar Charts

Kindergarten Graphing Worksheet

Read the bar graph and answer the questions.

Kid's Favourite Fruits

0 1 2 3 4 5 6 7 8 9 10

How many kids liked .....

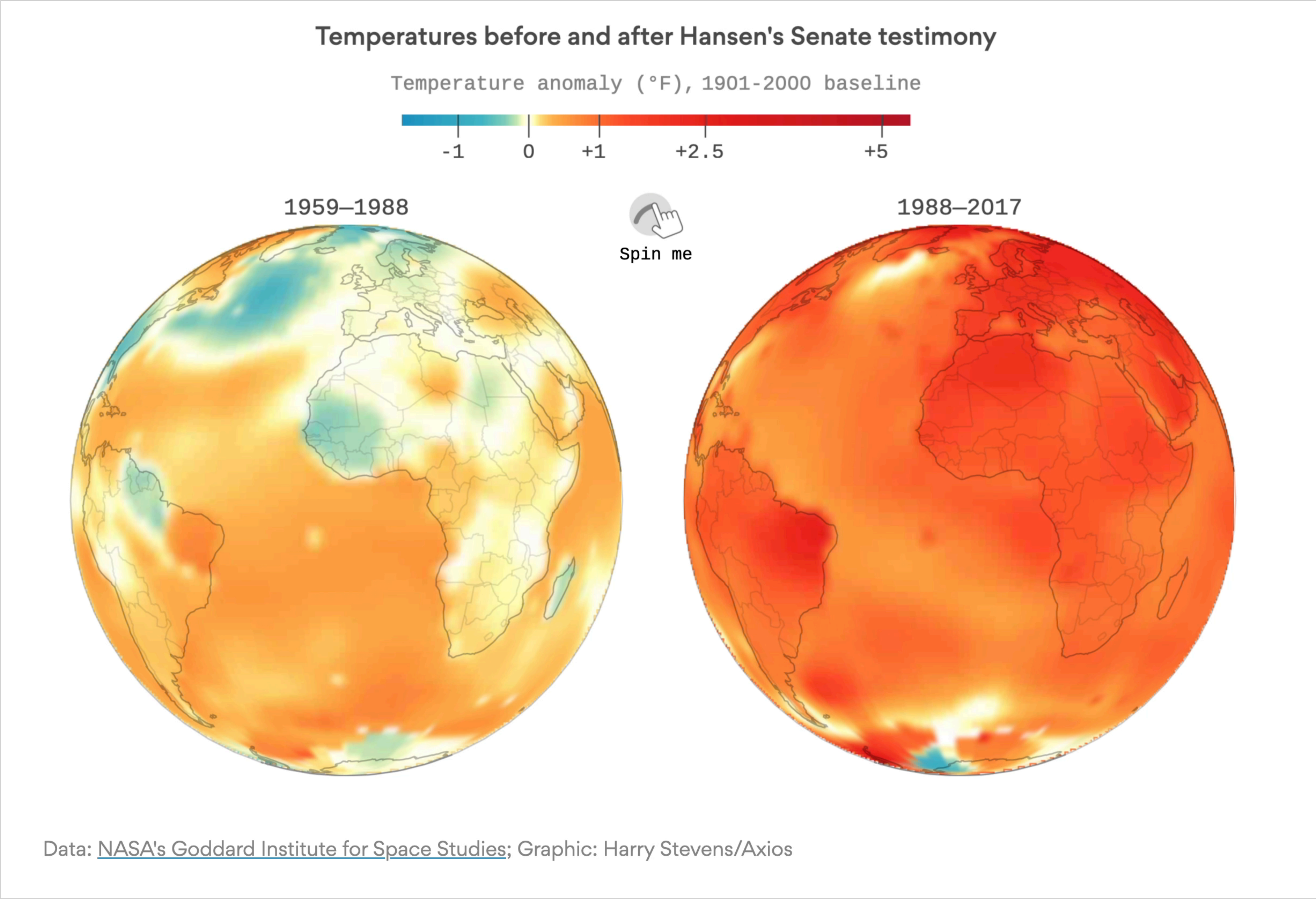
Apples ____?

Oranges ____?

Bananas ____?

Pears ____?

Online reading & math for K-5 www.k5learning.com

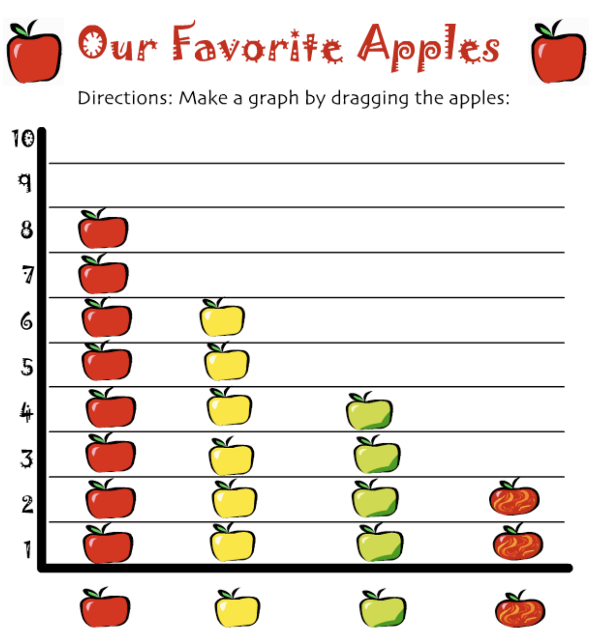


https://www.axios.com/how-much-earth-has-warmed-since-hansen-testified-b6f8fdb4-484e-477f-b8b6-6ee320994dc0.html

TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION

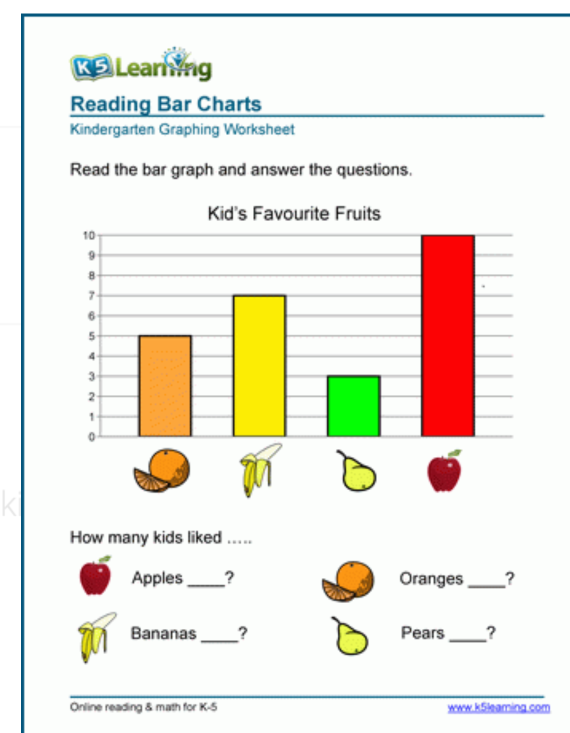
The 10 Questions

1. **Who** | Who is your audience? How expert will they be about the subject and/or display conventions?
2. **Explore-Explain** | Is your goal to explore, document, or explain your data or ideas, or a combination of these?
3. **Categories** |Do you want to show or explore pre-existing, known, human-interpretable, categories?
4. **Patterns** |Do you want to identify new, previously unknown or undefined patterns?
5. **Predictions & Uncertainty** | Are you making a comparison between data and/or predictions? Is representing uncertainty a concern?
6. **Dimensions** | What is the intrinsic number of dimensions (not necessarily spatial) in your data, and how many do you want to show at once?
7. **Abstraction & Accuracy** | Do you need to show all the data, or is summary or abstraction OK?
8. **Context & Scale** | Can you, and do you want to, put the data into a standard frame of reference, coordinate system, or show scale(s)?
9. **Metadata** | Do you need to display or link to non-quantitative metadata? (including captions, labels, etc.)
10. **Display Modes** | What display modes might be used in experiencing your display?



iz conversation! There's so much more to talk about.

)QViz? Try the About page.
and **participate** in 10QViz? Try the How to page.
ship behind 10QViz.org's questions? Write to ask for a draft of our research paper, Coltek



MENU

TEN QUESTIONS TO ASK WHEN CREATING A VISUALIZATION

The 10 Questions

1. **Who** | Who is your audience? How expert will they be about the subject and/or display conventions?
2. **Explore-Explain** | Is your goal to explore, document, or explain your data or ideas, or a combination of these?
3. **Categories** |Do you want to show or explore pre-existing, known, human-interpretable, categories?
4. **Patterns** |Do you want to identify new, previously unknown or undefined patterns?
5. **Predictions & Uncertainty** | Are you making a comparison between data and/or predictions? Is representing uncertainty a concern?
6. **Dimensions** | What is the intrinsic number of dimensions (not necessarily spatial) in your data, and how many do you want to show at once?
7. **Abstraction & Accuracy** | Do you need to show all the data, or is summary or abstraction OK?
8. **Context & Scale** | Can you, and do you want to, put the data into a standard frame of reference, coordinate system, or show scale(s)?
9. **Metadata** | Do you need to display or link to non-quantitative metadata? (including captions, labels, etc.)
10. **Display Modes** | What display modes might be used in experiencing your display?

Now, visit the 10QViz conversation! There's so much more to talk about.

Curious about the **origins** of 10QViz? Try the About page.
Want to learn **how best to use** and **participate** in 10QViz? Try the How to page.
Want to read about the **scholarship** behind 10QViz.org's questions? Write to ask for a draft of our research paper, Coltekin & Goodman 2019.

10QViz.org

Beyond-the-Book Thinking in Modern (STEM) Education

Alyssa A. Goodman

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

RADCLIFFE INSTITUTE
FOR ADVANCED STUDY
HARVARD UNIVERSITY

HarvardX

More WWTA

ThinkSpace Labs: Teaching Seasons and Moon Phases with WorldWide Telescope

Patricia **Udomprasert,** Harry **Houghton,** Susan **Sunbury,** Erin **Johnson,** Erika **Wright,** Alyssa **Goodman,** Philip **Sadler**

Harvard-Smithsonian Center for Astrophysics

Julia **Plummer,** Abha **Vaishampayan**, Kyungjin **Cho**

Pennsylvania State University

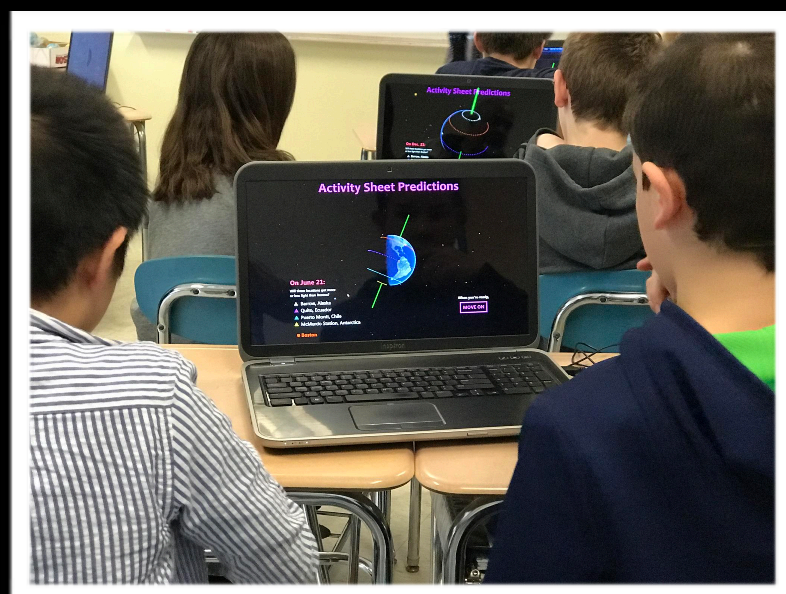
Helen Zhihui **Zhang**

Boston College

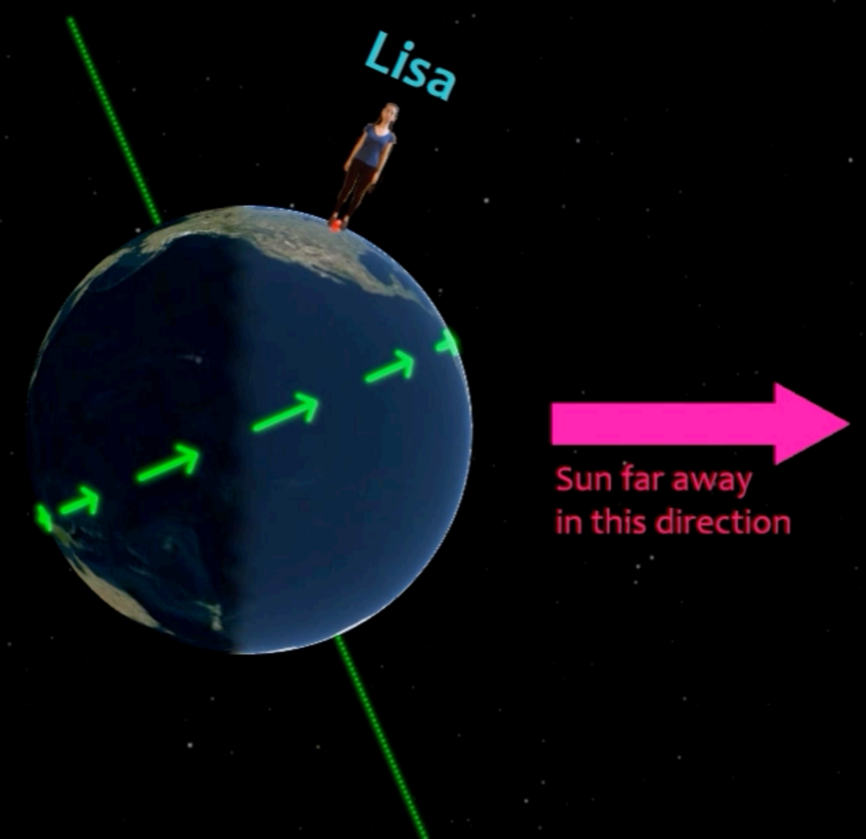
This work has been funded by NSF awards DRL-1503395 & 1502798

Project OVERVIEW

ThinkSpace labs teach astronomy while supporting spatial thinking skills, like imagining a scene from multiple viewpoints.



DECEMBER 21 in BOSTON
PATH OF THE SUN



EARTH
MODELS

Distractor-driven multiple choice (DDMC) questions from the Astronomy and Space Science Concept Inventory (Sadler et al, 2009): 10 questions about Seasons on pre/post assessments.

8. The main reason for it being hotter in summer than in winter is:

   a. the Earth's distance from the Sun changes.

   ✓ b. the Sun is higher in the sky.

   c. the distance between the northern hemisphere and the Sun changes.

   d. ocean currents carry warm water north.

   e. the Sun produces heat and light at a faster rate in the summer.

	Post "typical" Instruction (Sadler et al)	Post ThinkSpace Instruction
a.		8%
b.	9%	55%
c.		33%

Distractor-driven multiple choice (DDMC) questions from the Astronomy and Space Science Concept Inventory (Sadler et al, 2009): 9 questions about Moon Phases & Eclipses on pre/post assessments.

2. One night you looked at the Moon and saw this:

A few days later you looked again and saw this:

Why did the Moon change shape?

A. Clouds covered a different amount of the Moon.
B. The Moon moved out of the Earth's shadow.
C. The Moon moved out of the Sun's shadow.
D. The Moon is black and white and rotates on its axis once a month.
✓ E. We see a different amount of the lit up side of the Moon.

	Post "typical" Instruction (Sadler et al)	Post ThinkSpace Instruction
B		20%
C		13%
E	33%	65%

Student Gains: Moon Phases & Seasons Questions

$$\text{Cohen's d Effect Size} = \frac{\text{Average(Posttest Score - Pretest Score)}}{\text{stdev(Pretest Score)}}$$

WWT Moon Phases: Cohen's d=1.2±0.2; N=330

WWT Seasons: Cohen's d=1.5±0.2; N=290

Cohen's d ~ 0.2 → small effect

Cohen's d ~ 0.5 → medium effect

Cohen's d >0.7 → large effect

Download ThinkSpace Curriculum:
wwtambassadors.org

Use WWT:
worldwidetelescope.org

Questions?
email: pudompra@cfa.harvard.edu

Also use Jais’ spreadsheet