Curriculum & ASTRONOMY

A review of astronomy in the school curriculum of OECD Countries

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Goals & Motivation

- A rich picture of the current state of affairs of science education with emphasis on astronomy.

- Knowing what is happening currently across the world, will allow researchers engaged in policy and practice and politicians to plan for and implement future directions in astronomy education with informed knowledge.

OECD

China and South Africa

Curricula Studied

- A total of **53** national curricula from **37** countries were reviewed.
- **UK** is different for **England, Wales, Northern Ireland and Scotland**.
- Whilst for the case of the **USA**, we focused on the states of **Texas**, **Kansas** and **California**.
- In addition, **Canada** has different curricula for each of its provinces.
- Although, **Germany** and **Switzerland** too had different curricula for each province/canton, our analysis did not focus on each individual province/canton.

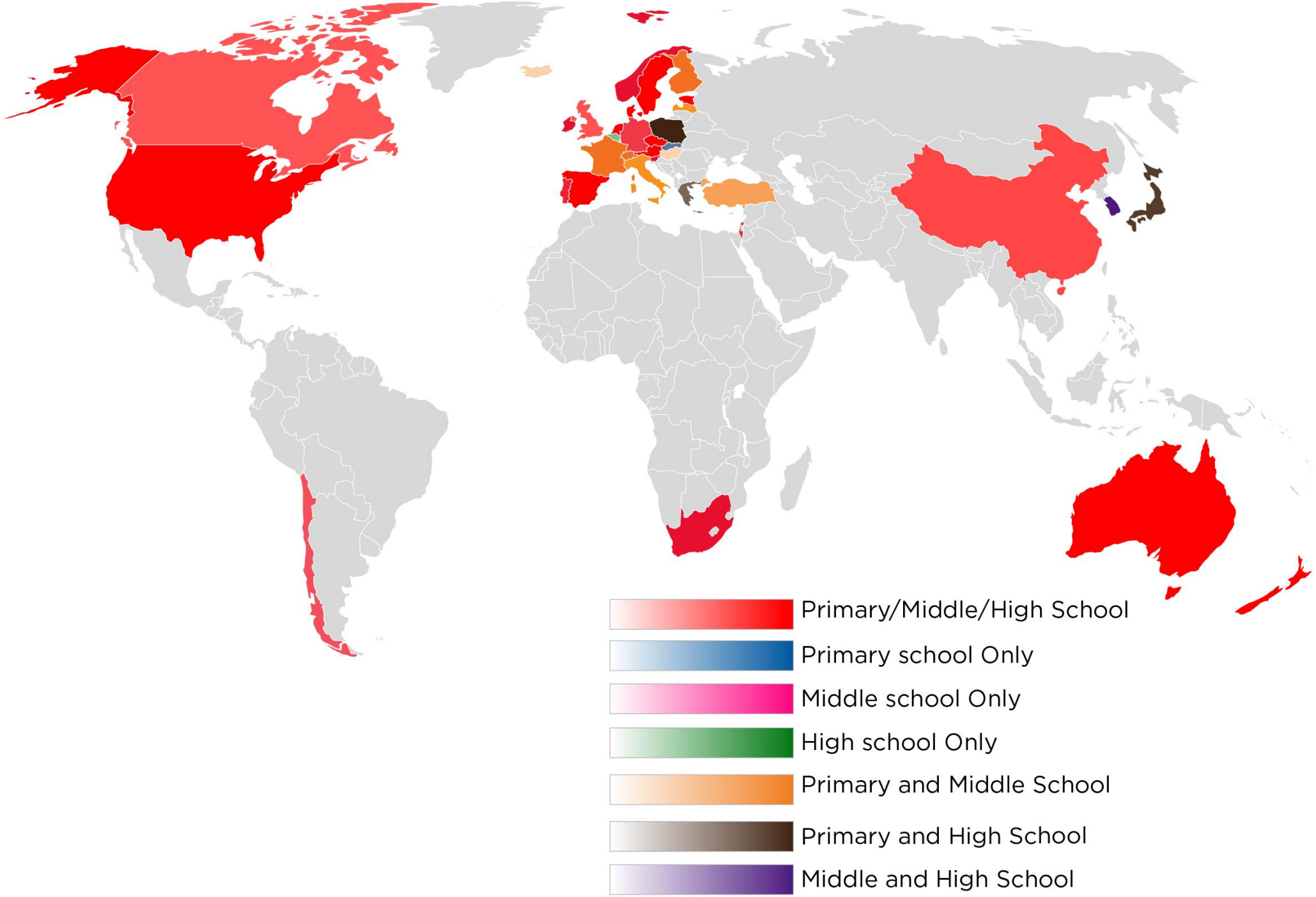
Curriculum, Pedagogy and Evaluation

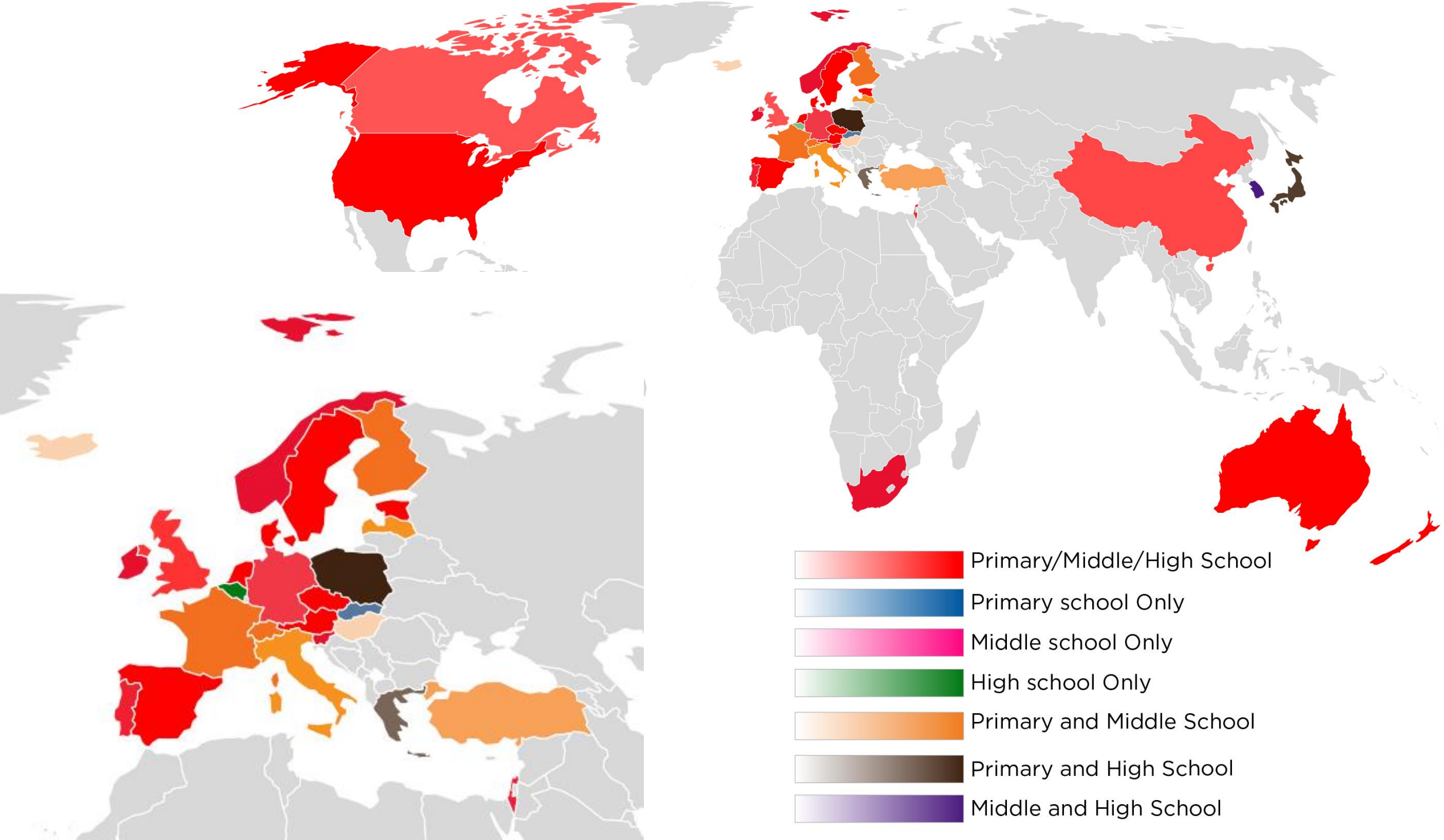
- Bernstein (1975), claims that all schools around the world share three message systems: curriculum, pedagogy and assessment. “Formal education knowledge can be considered to be realized through three message systems: curriculum, pedagogy, and evaluation. Curriculum defines what counts as a valid knowledge, pedagogy defines what counts as a valid transmission of knowledge, and evaluation defines what counts as a valid realization of this knowledge…"

Curriculum, Objectives and Slavery.

- Bobbit’s explanation was that curriculum provides educators with a set of procedures/experiences enabling students to attain certain objectives, this notion has in ways been the foundation of curricula across countries.

- Curriculum has become innately fused into education systems, and teachers at times have become “slaves” to the curriculum.


Primary/Middle/High School
Primary school Only
Middle school Only
High school Only
Primary and Middle School
Primary and High School
Middle and High School


Primary/Middle/High School
Primary school Only
Middle school Only
High school Only
Primary and Middle School
Primary and High School
Middle and High School

Frequency of Astronomy

- Astronomy as an elective was quite rare with only, 9 out of the 53 curricula (17%), offering it as a subject within the general curriculum. Predictably, these electives provided in-depth and explicit guidance within the curriculum documents.

- Our analysis showed that 44 out of the 53 curricula (83%), included astronomy-related topics in grade 6, while 40 included astronomy in grade 1. In grades 2 and 7, this number drops to 28 out of 53 (52.8%).

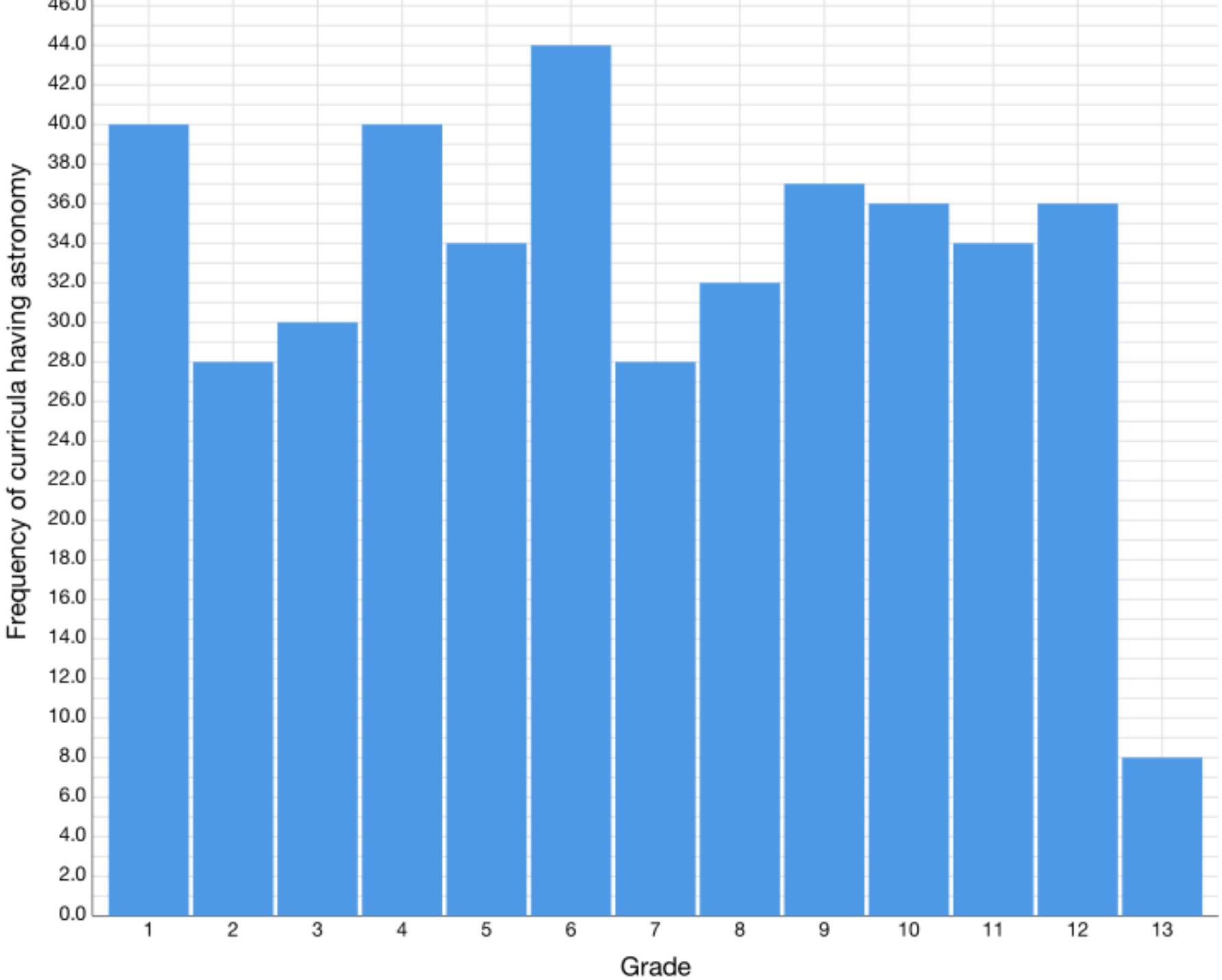
Frequency of Astronomy

- Out of the 53 curricula, 14 of them (26.4%), had astronomy-related topics explicitly mentioned in all grades from 1 to 12.

- The least occurrence was having astronomy-related topics in only two grades, this made up 3.8% of the total curriculla.


Iceland
Hungary
Greece
Germany
France
Finland
Estonia
Denmark
Czech Republic
China
Chile
Canada - Saskatchewan
Canada - Quebec
Canada - Ontario
Canada - Nunavut
Canada - Nova Scotia
Canada - Northwest Territories
Canada - Newfoundland and Labrador
Canada - New Brunswick and Prince Edward Island
Canada - Manitoba
Canada - British Columbia
Canada - Alberta
Belgium
Austria
Australia
1 2 3 4 5 6 7 8 9 10 11 12 13
Grade


US, Texas
US, Kansas
US, California
UK, Wales
UK, Scotland
UK, Northern Ireland
UK, England
Turkey
Switzerland
Sweden
Spain
South Korea
South Africa
Slovenia
Slovak Republic
Portugal
Poland
Norway
New Zealand
Netherlands
Luxembourg
Latvia
Japan
Italy
Israel
Ireland
1 2 3 4 5 6 7 8 9 10 11 12 13
Grade


Frequency of curricula having astronomy
46.0
44.0
42.0
40.0
38.0
36.0
34.0
32.0
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1
2
3
4
5
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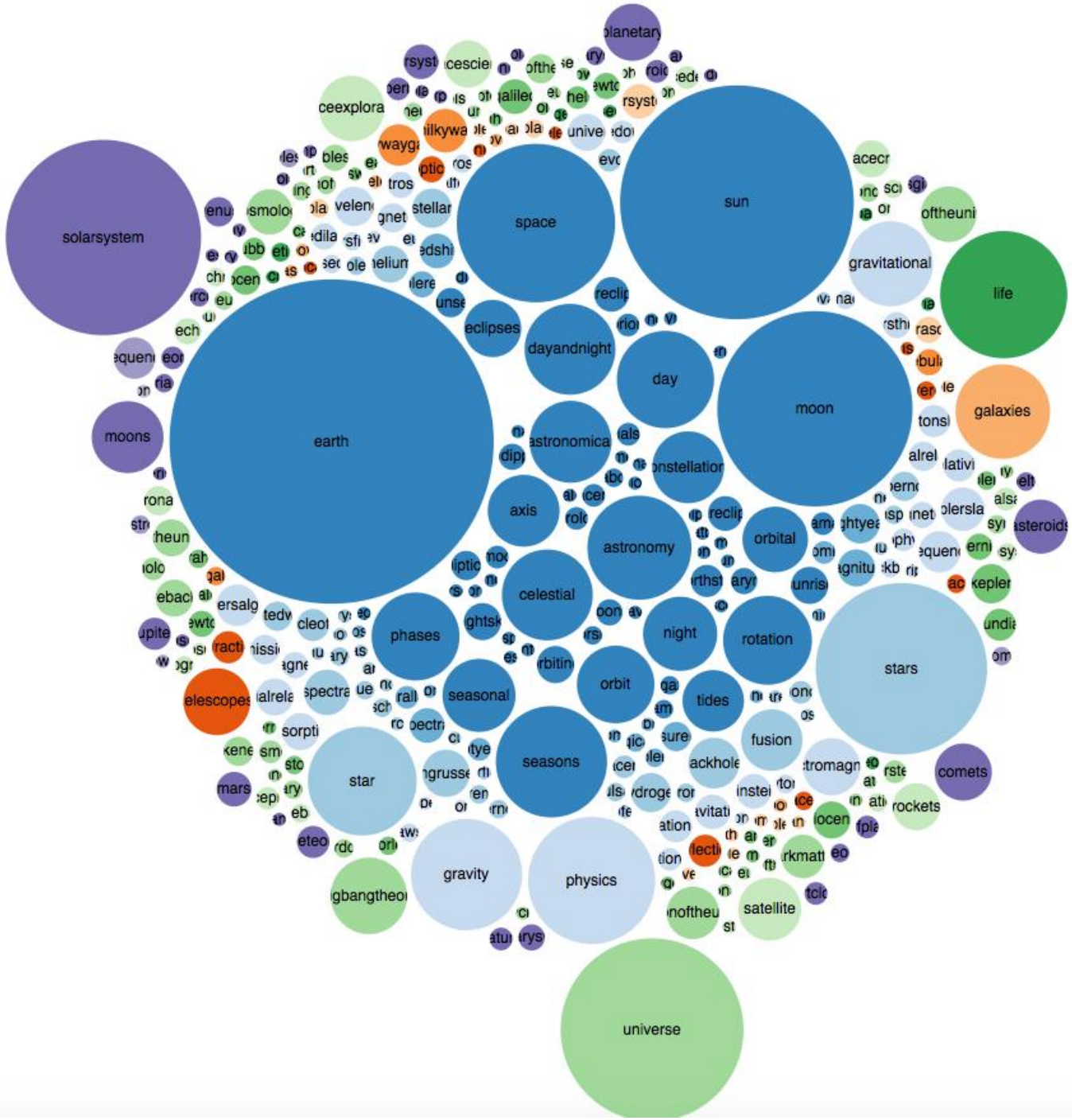
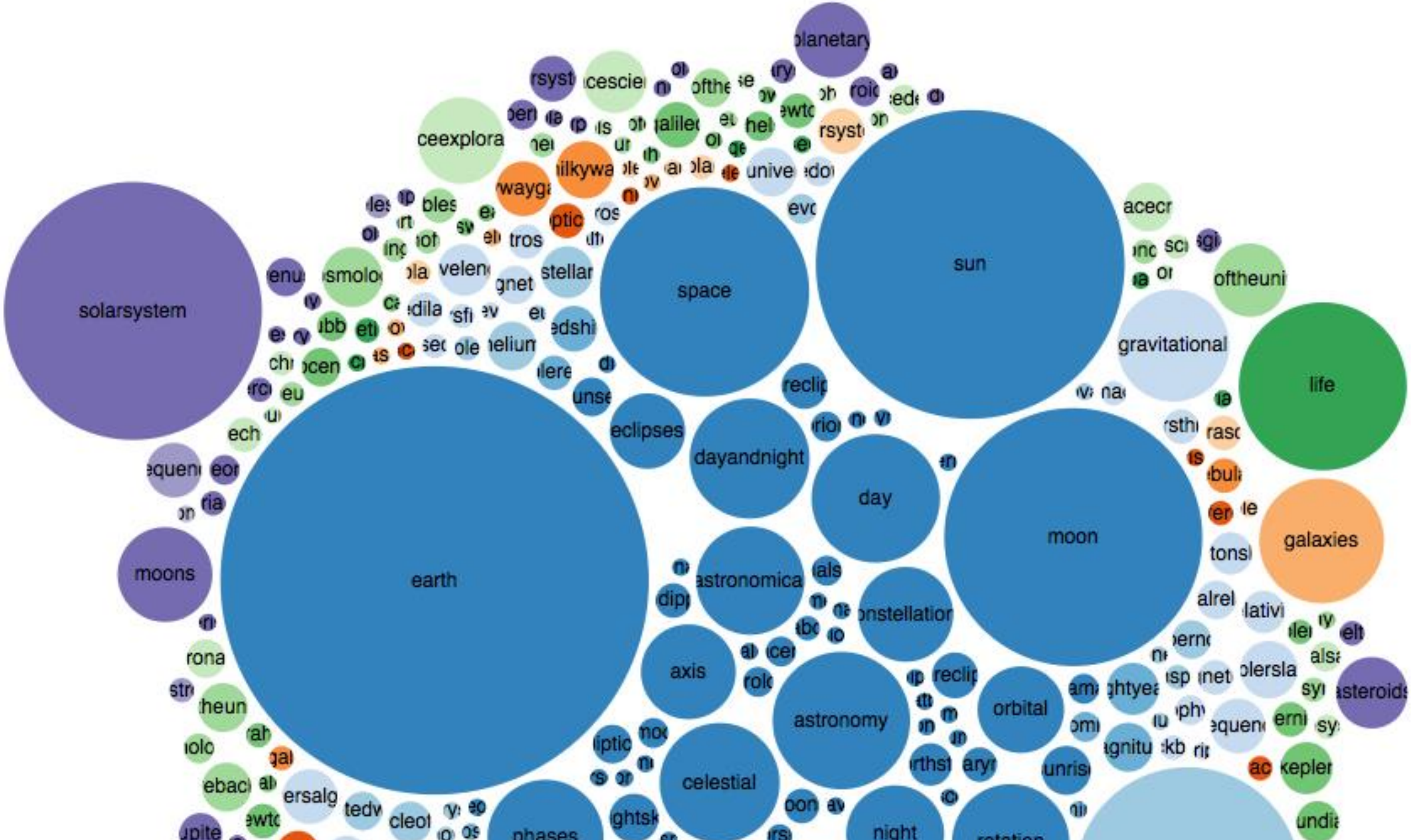
8
9
10
11
12
13
Grade

- Visualisation of all 368 words, size of bubbles represent the number of occurrences of each word across the 53 curricula.




planetary
solarsystem
space
sun
earth
moon
life
galaxies
moons
gravitational
dayandnight
day
eclipses
astronomical
constellation
axis
astronomy
orbital
celestial
phases
night
rotation
asteroids
kepler
oftheuni
ceexplora
stellar
tros
velen
smolo
ubb
ersalg
tedv
cleot
rona
theun
ebac
upite
ech
equen
eon
ria
rsyst
cescie
galile
wayga
ilkywa
univer
acecr
sci
rasc
tonsi
alrel
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alsa
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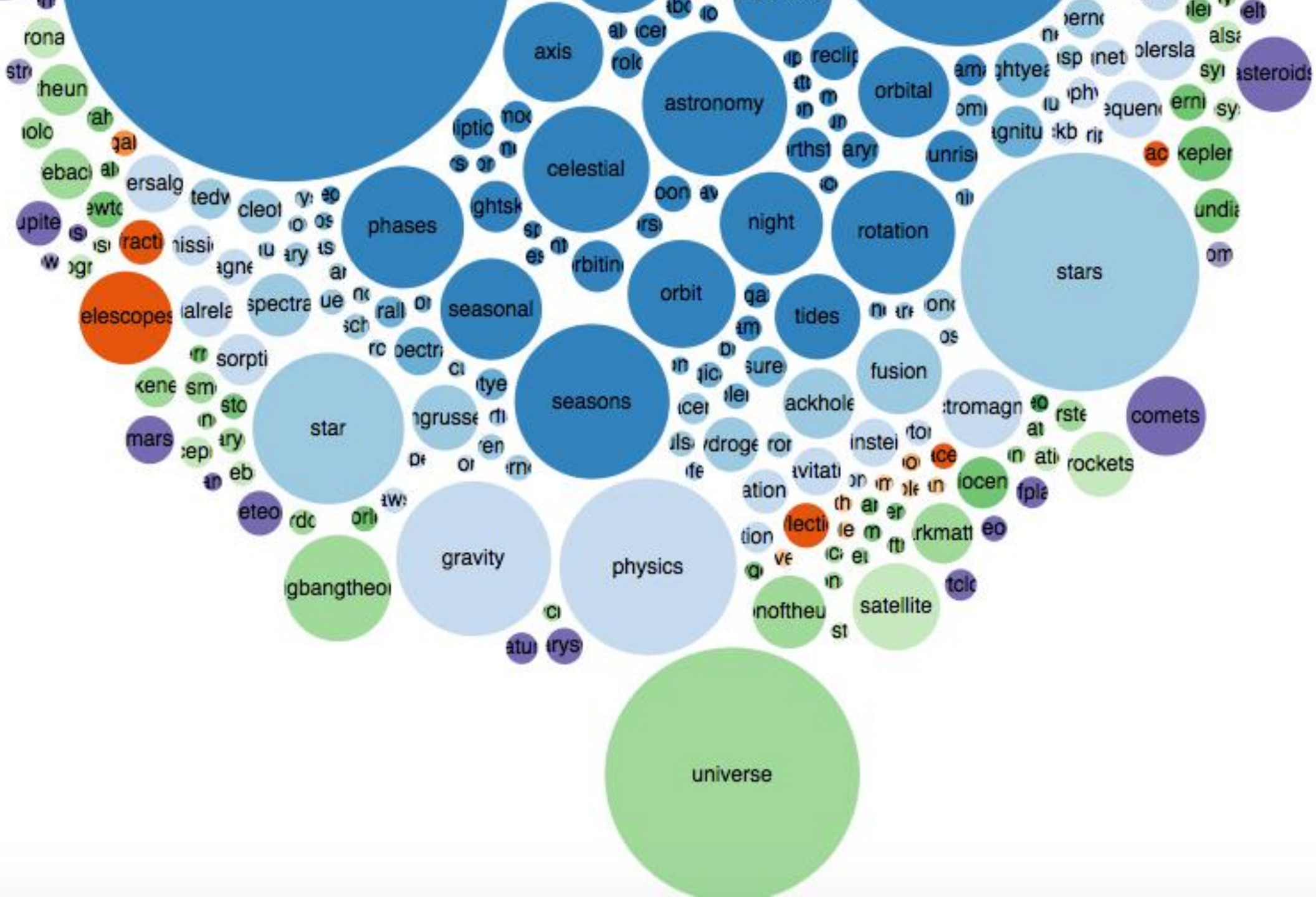
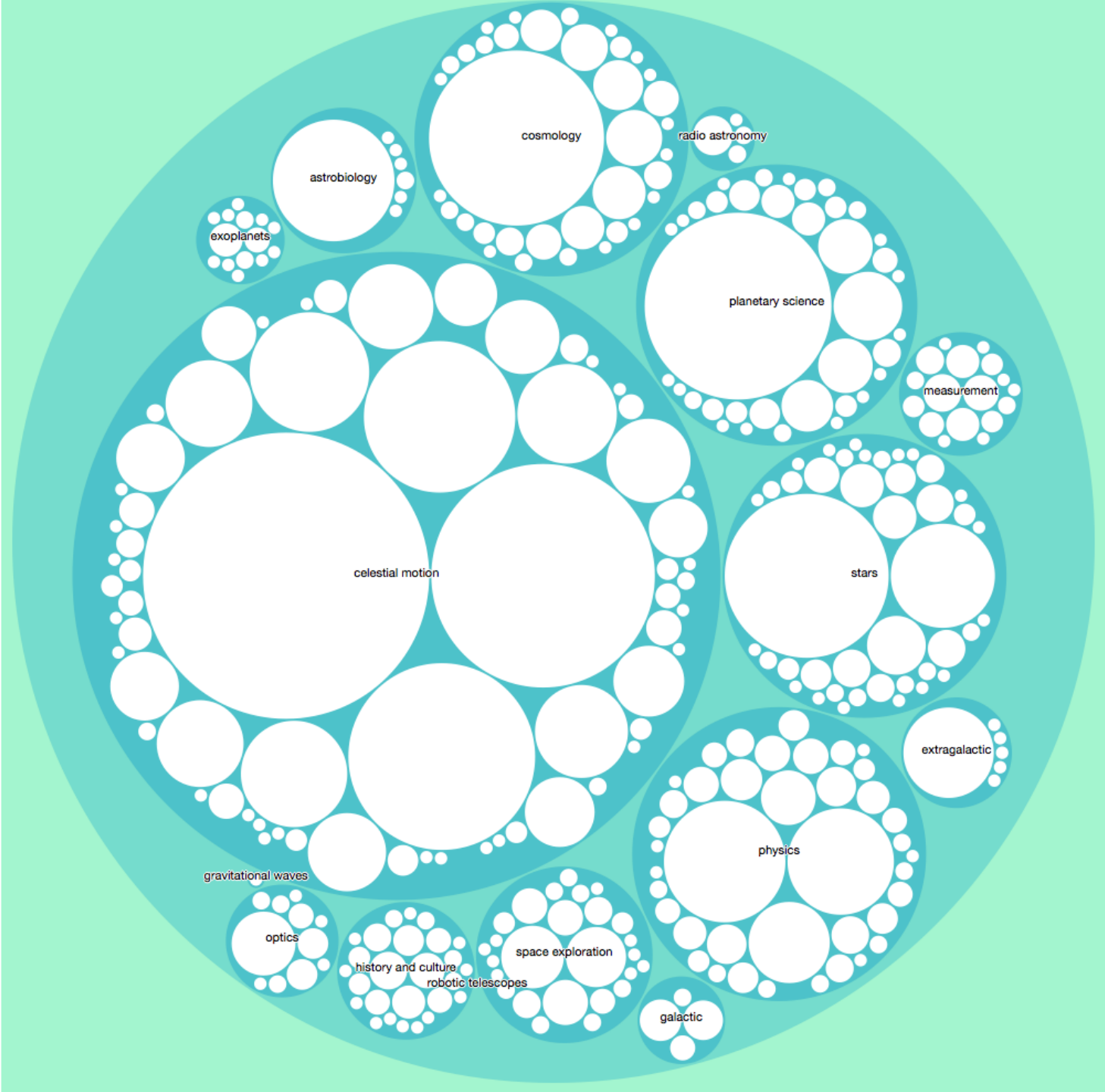
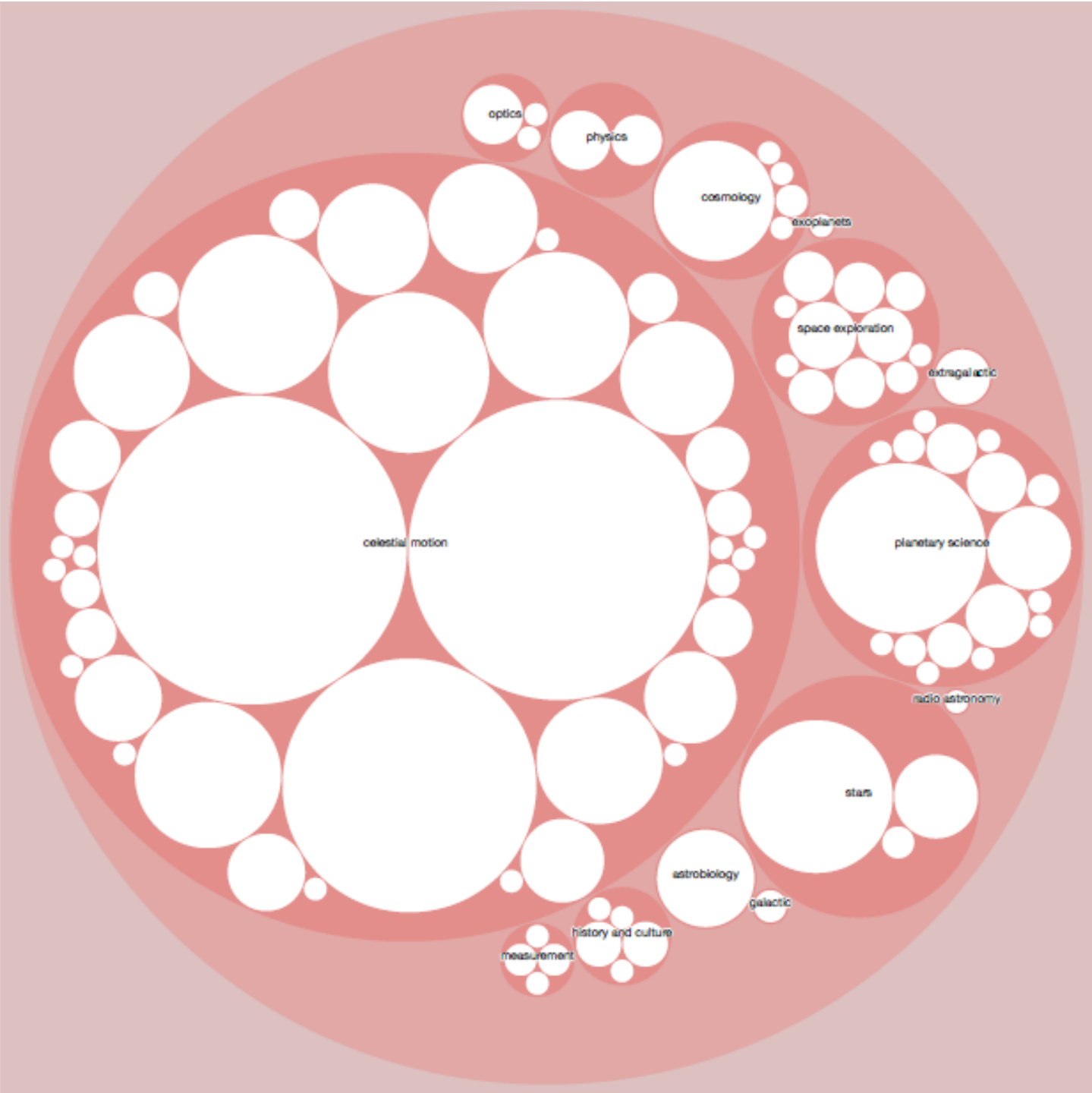
iv


axis
astronomy
orbital
celestial
phases
night
rotation
stars
seasonal
orbit
tides
seasons
fusion
star
comets
rockets
gravity
physics
satellite
universe
asteroids
kepler
telescopes
mars

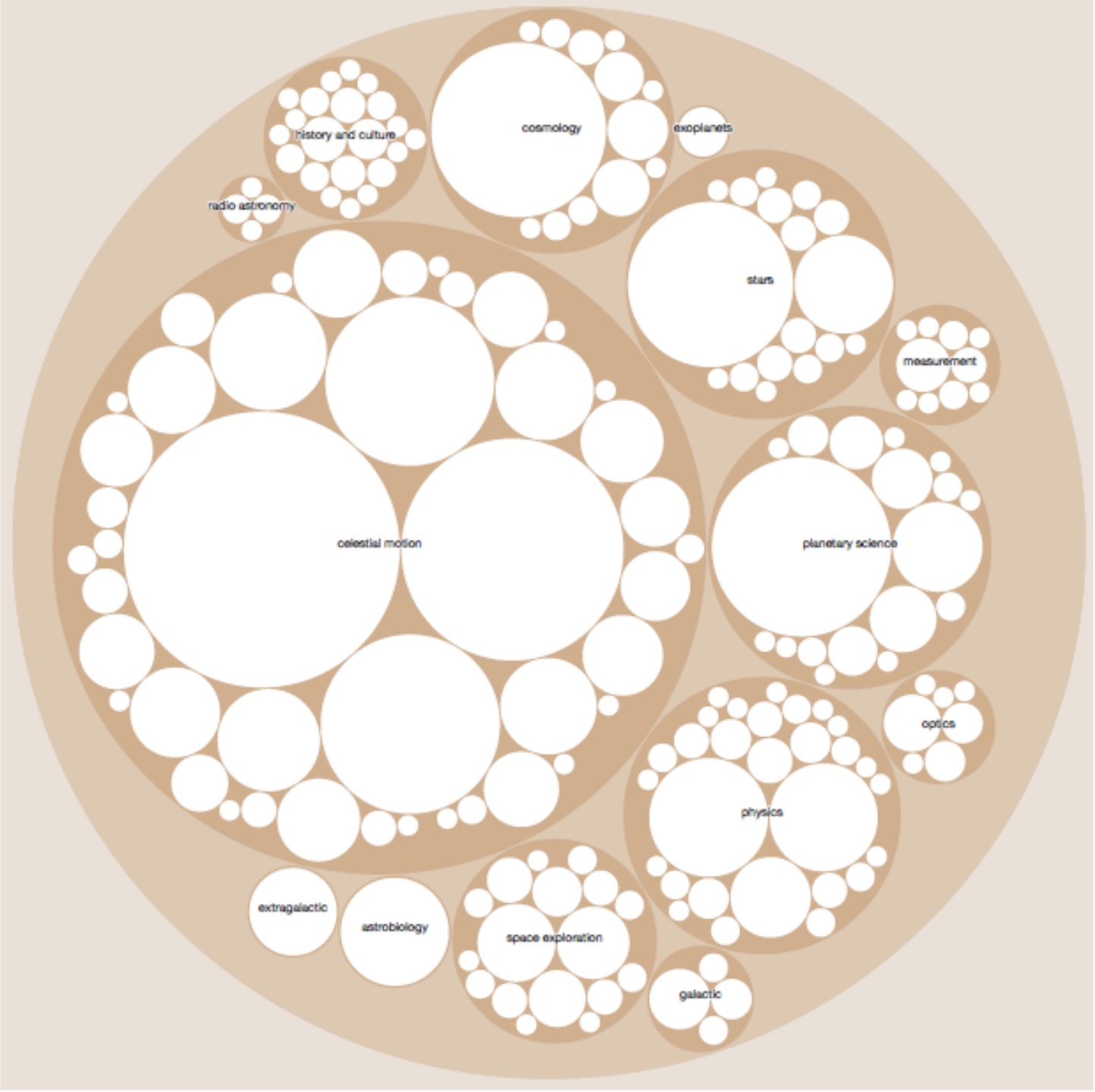
- Visualisation of all 368 words within each of the 16 categories. Size of bubbles represent the number of occurrences of each word across the 53 curricula.



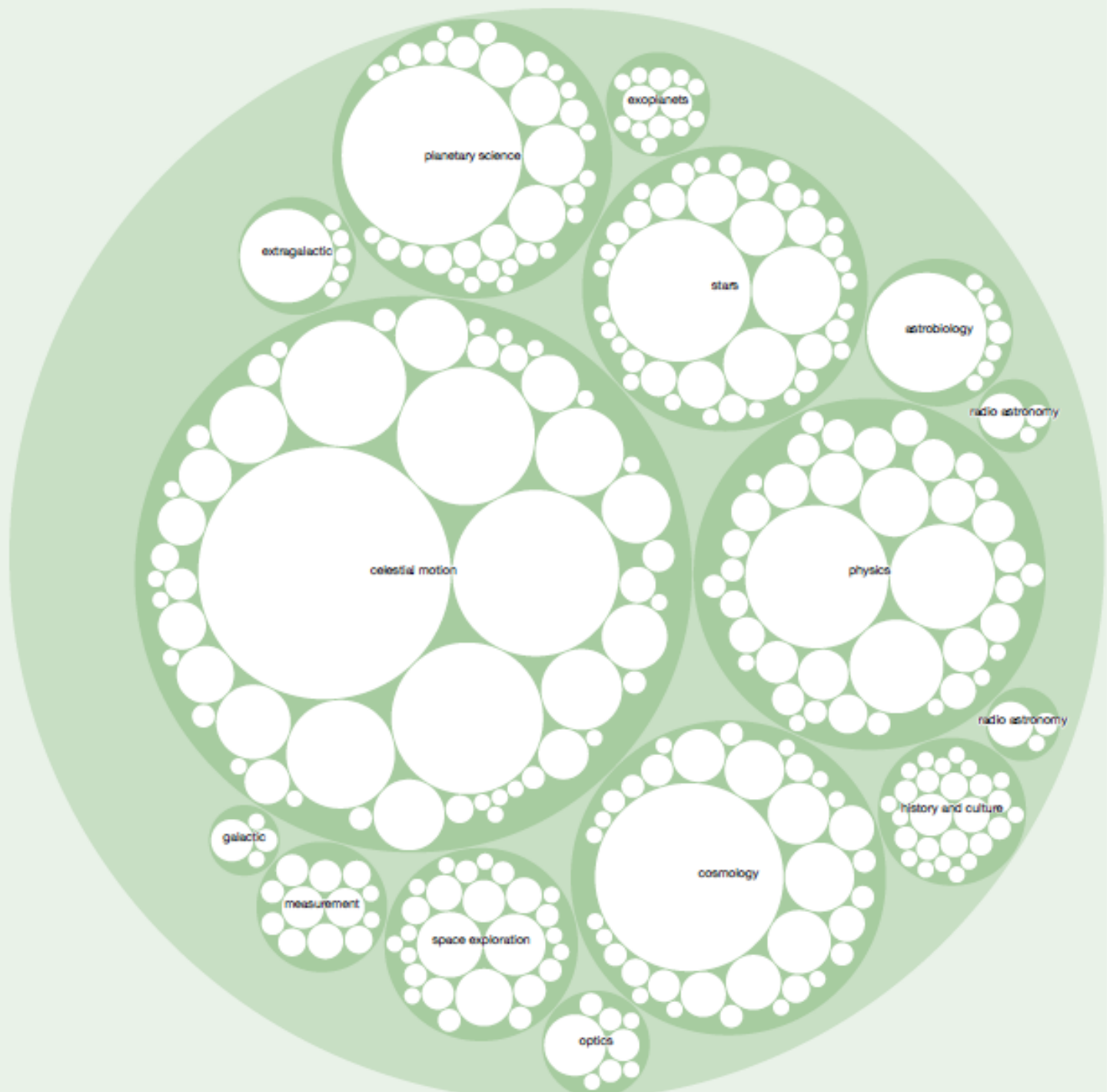
- Primary School

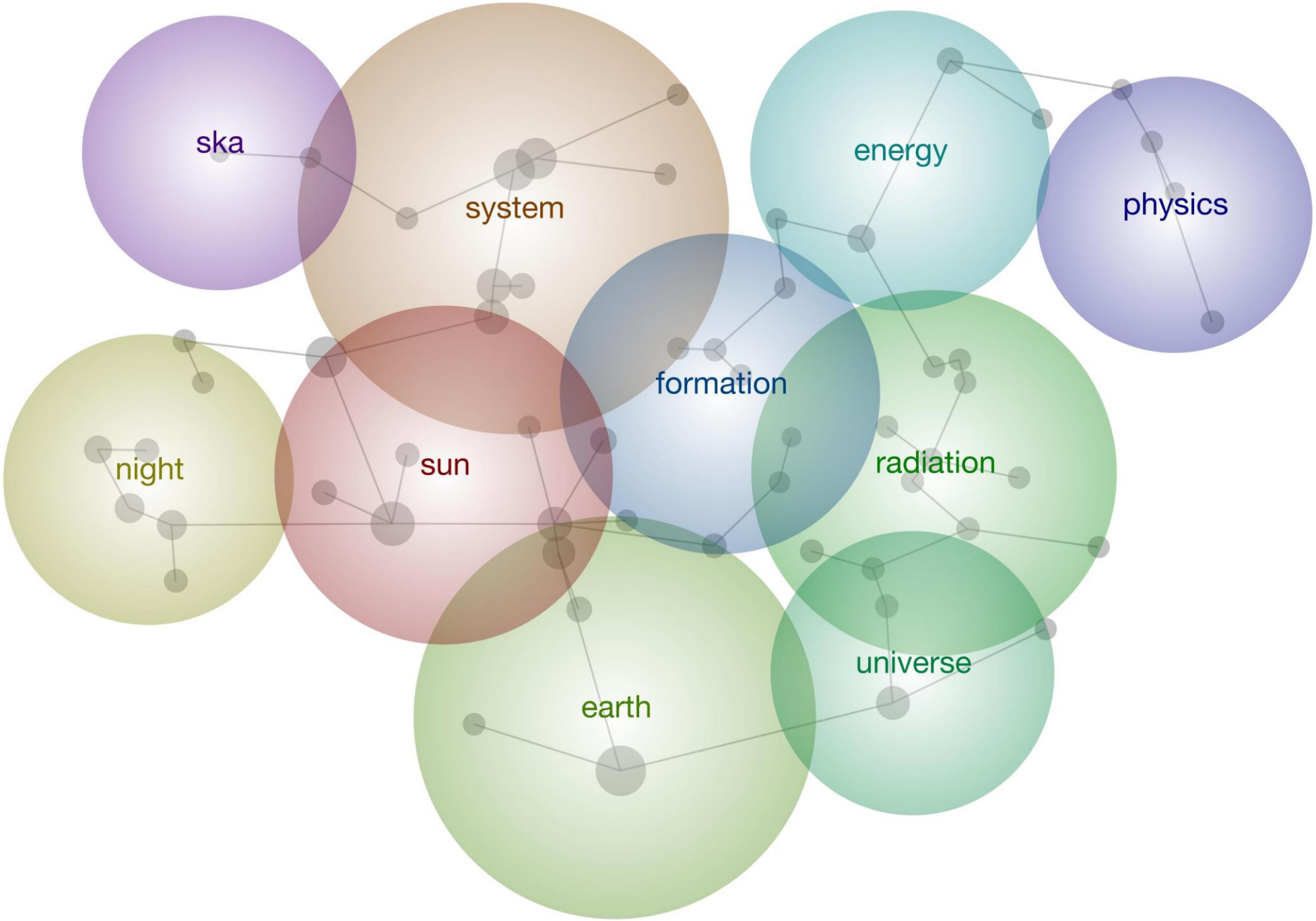


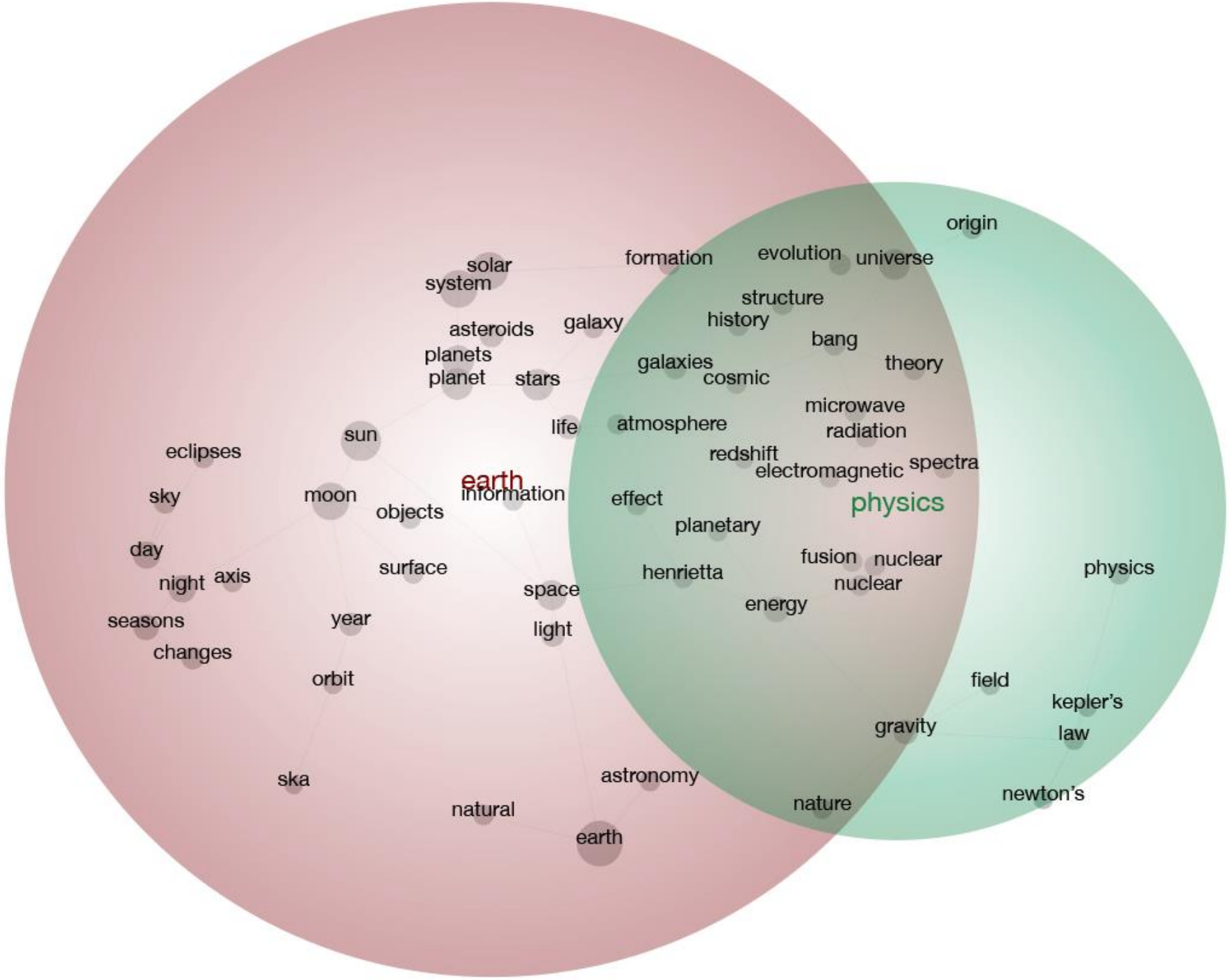
- Middle School



- High School


exoplanets
planetary science
extragalactic
stars
astrobiology
radio astronomy
celestial motion
physics
radio astronomy
history and culture
galactic
cosmology
measurement
space exploration
optics


ska
system
energy
physics
formation
night
sun
radiation
universe
earth


earth
physics
solar
system
formation
evolution
universe
origin
structure
history
bang
theory
asteroids
galaxy
planets
planet
stars
galaxies
cosmic
microwave
radiation
life
atmosphere
sun
eclipses
redshift
electromagnetic
spectra
sky
moon
information
effect
objects
planetary
day
fusion
nuclear
surface
henrietta
physics
night
axis
space
nuclear
energy
seasons
year
light
changes
orbit
field
kepler's
gravity
law
ska
astronomy
nature
newton's
natural
earth

Indigenous astronomy

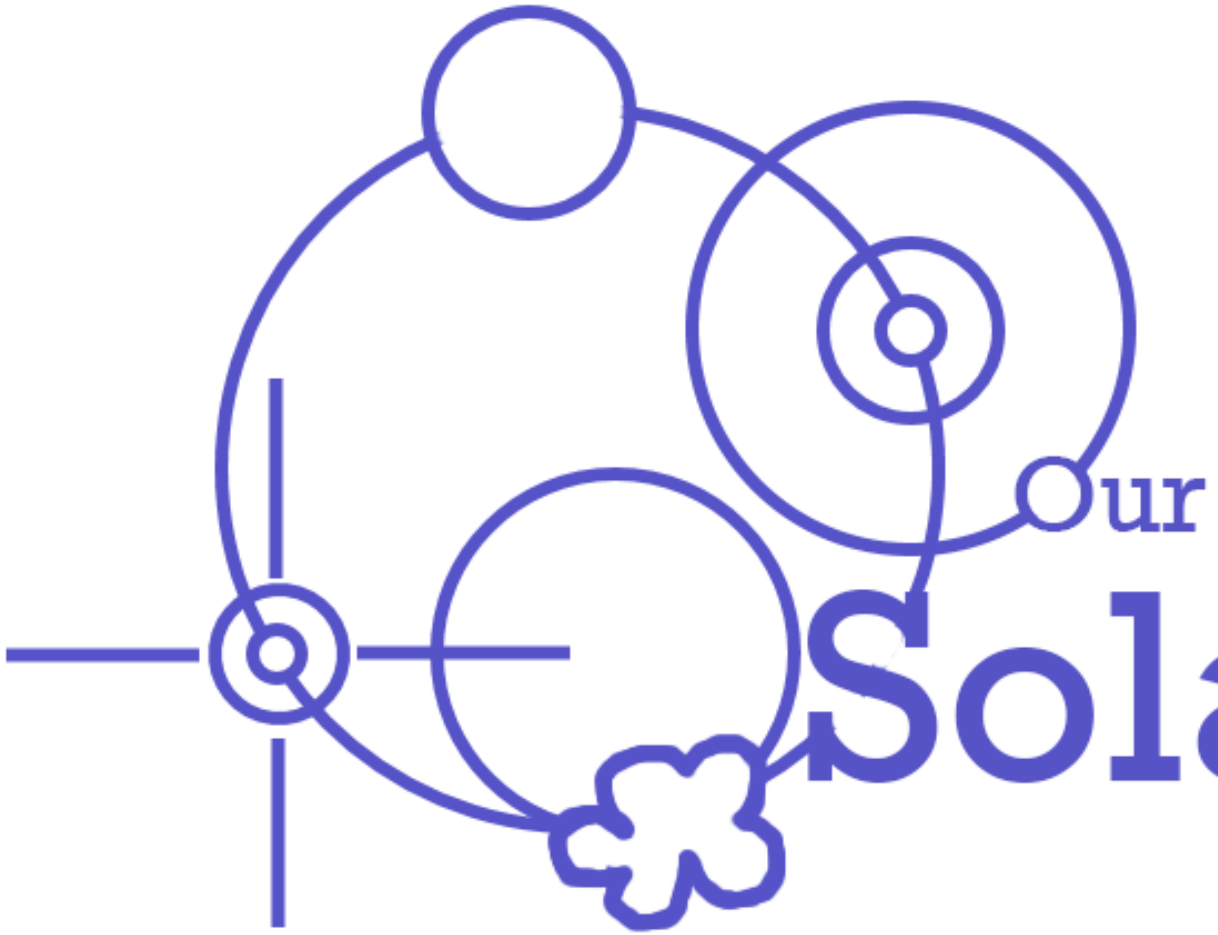
- Indigenous astronomy although not prevalent across curricula has occurrences in 3 out of the 37 countries – Canada, New Zealand, and Norway. However, the Australian Curriculum has stated three cross-curriculum priorities have to be addressed by schools in their curriculum:
- Aboriginal and Torres Strait Islander histories and cultures
- Asia and Australia's engagement with Asia
- Sustainability

- Whilst the above three do not explicitly fall under astronomy, they do provide teachers with the opportunity to incorporate Cultural Astronomy into various subject areas, not limited to science.

International Baccaleureate

- The IB Diploma Program (DP) Physics course (International Baccalaureate Organization IBO, 2017) is a general syllabus aimed at University admission.
- Astronomy concepts are covered to varying degrees throughout the compulsory IB core components shows a general overview of the components, both Standard and Higher Level, where astronomy is integral to the information being delivered in the unit.
- Astronomical concepts are spread over the entire course, and in many instances, garner improved student interest and interaction. In addition, the IB Physics course also offers Astrophysics as an option for the two year course. The option covers stellar quantities, stellar characteristics, stellar evolution and cosmology.
- Extended Essays

An example of hitting the curricula



Our Solar Siblings

History

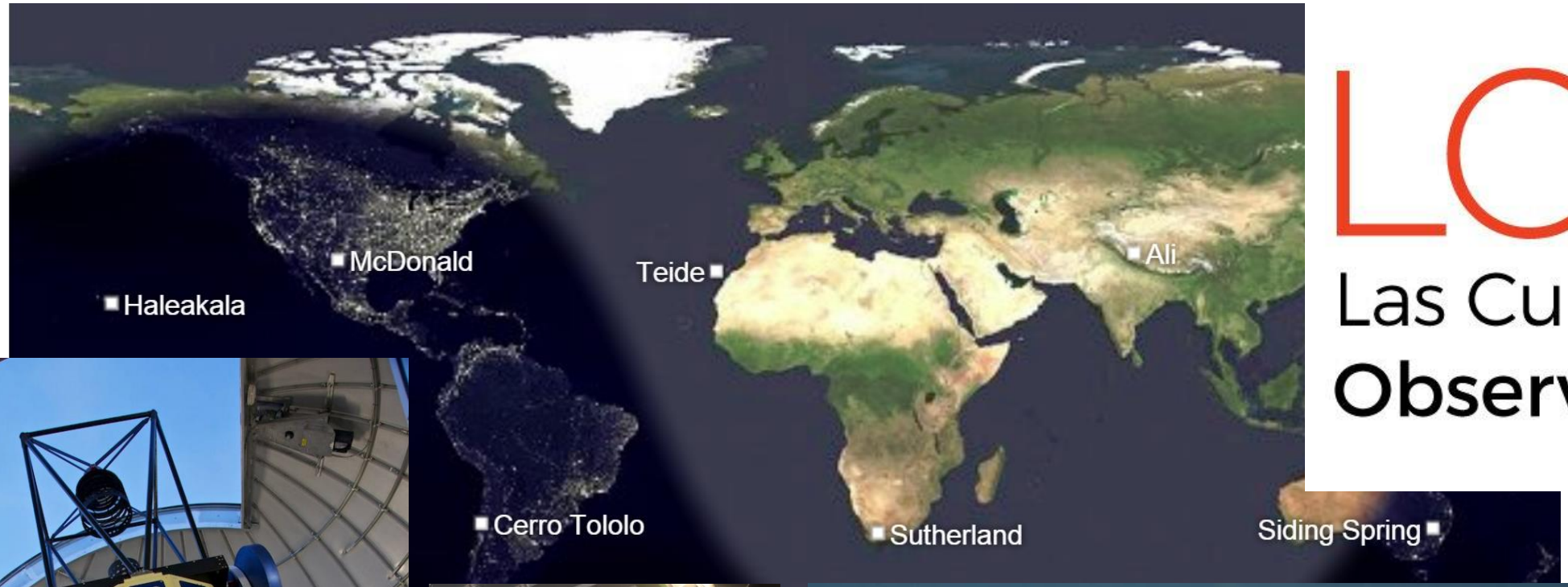
- Our Solar Siblings began officially, after ethics approval, in October 2014. www.oursolarsiblings.com based on work started in 2010.

- Primary focus is on being a curriculum and support resource for in-service teachers to teach astronomy at Years 9/10. Although it also has been significantly elsewhere

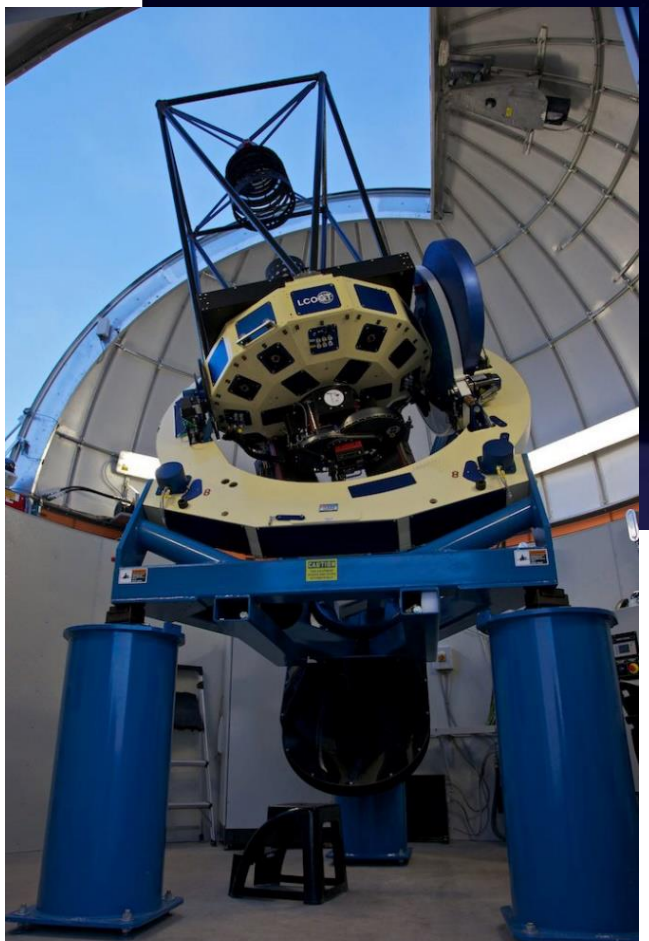
Our Solar Siblings

Las Cumbres Observatory

- Main Partner. A growing network of over 20 large research telescopes in 8 locations around the world accessible remotely.
- Official Education Partner since 2014
- They concentrate on provision of telescope time and a quality user interface.
- We facilitate the plausible active connection of this resource for education use.

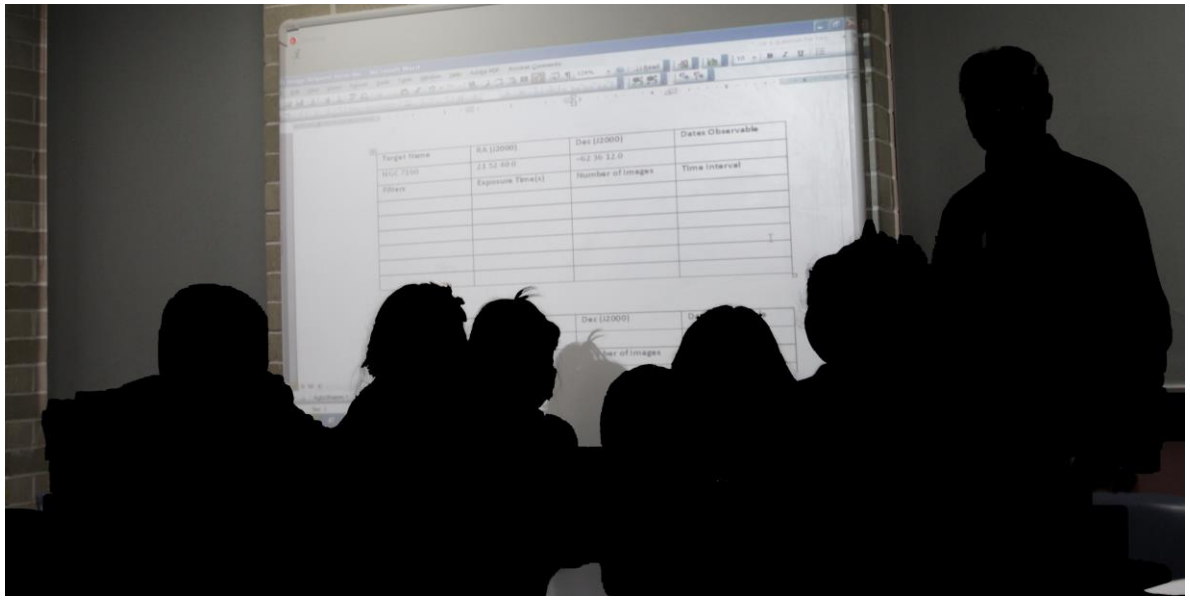


LCO
Las Cumbres Observatory



LCO

Our Solar Siblings



Goals

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- Involve the nontrivial use of real astronomical data from a real research grade telescope;
- Enable students, or a smaller subset that so desire, to take their research to a natural scientific conclusion in the form of a scientific publication.

Approaches

- Facilitate and develop everyday in-class teachers to use robotic telescopes to teach astronomy towards the end of compulsory science schooling. (Year 10 in Australia)
- Direct mentoring of high school students undertaking independent research projects within a variety of contexts, both inside and outside the formal school curriculum.
- Active and open development of scaffolds, mentoring and support for other projects using robotic telescopes in the classroom all around the world.

Year 10 Australian Curriculum

- The universe contains features including galaxies, stars and solar systems, and the Big Bang theory can be used to explain the origin of the universe (ACSSU188)

- Three weeks.

Science as a human endeavour

- Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE191)

- Advances in scientific understanding often rely on technological advances and are often linked to scientific discoveries (ACSHE192)

Science as a human endeavour

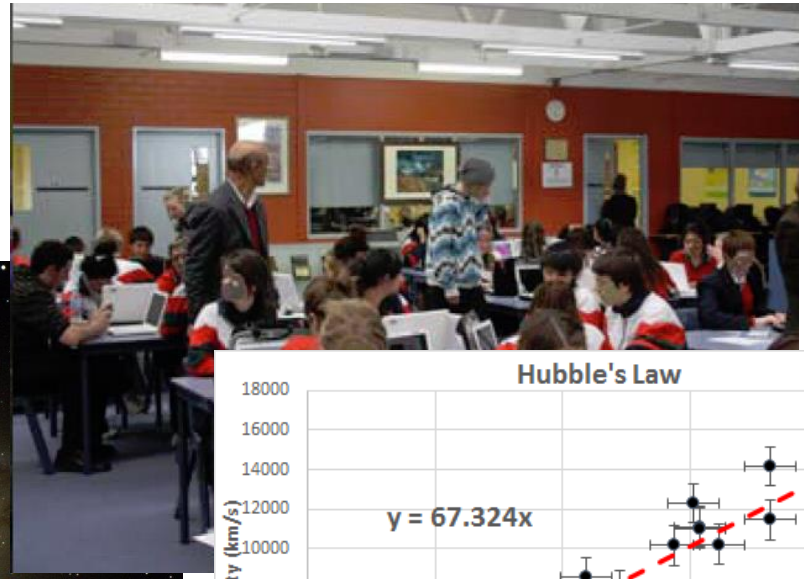
- People use scientific knowledge to evaluate whether they accept claims, explanations or predictions, and advances in science can affect people’s lives, including generating new career opportunities (ACSHE194)

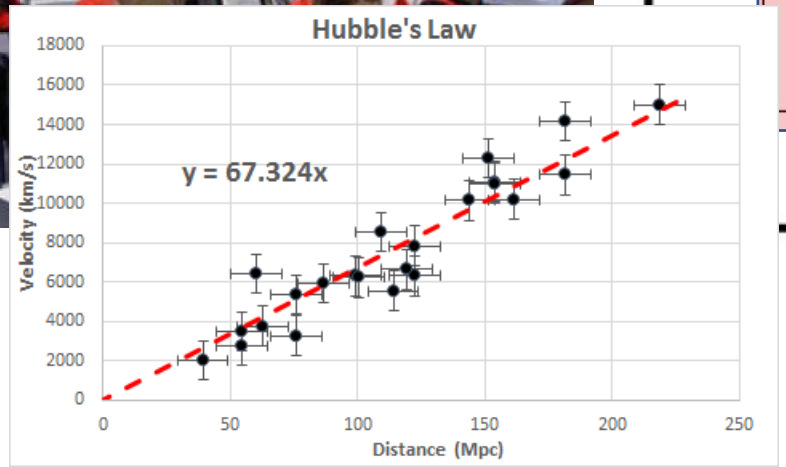
- Values and needs of contemporary society can influence the focus of scientific research (ACSHE230)

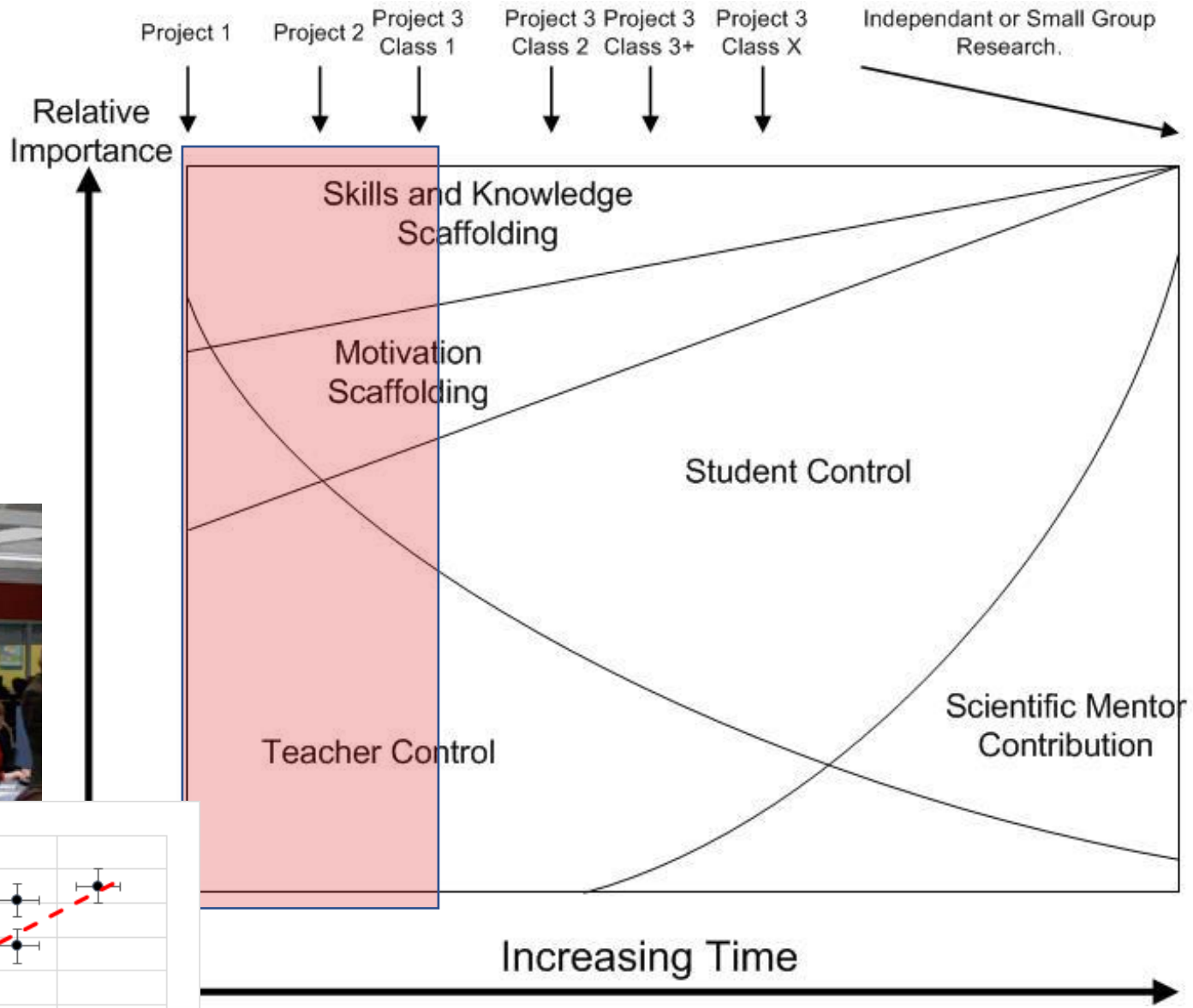
Science Inquiry Skills

- Formulate questions or hypotheses that can be investigated scientifically (ACSIS198)
- Plan, select and use appropriate investigation types, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS199)
- Select and use appropriate equipment, including digital technologies, to collect and record data systematically and accurately (ACSIS200)
- Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS203)
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence (ACSIS204)
- Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS205)
- Critically analyse the validity of information in primary and secondary sources, and evaluate the approaches used to solve problems (ACSIS206)
- Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations (ACSIS208)

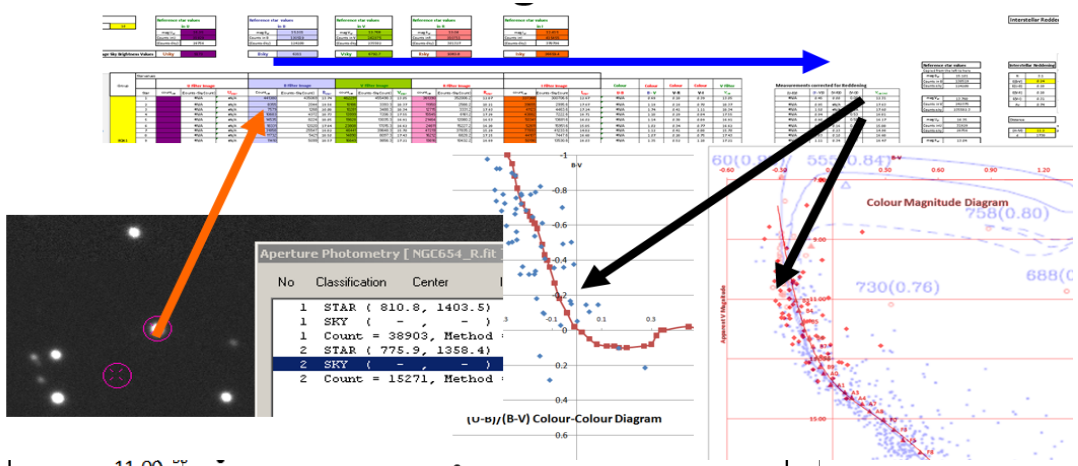
- Most students will go through planning on observation session, familiarisation with objects in the sky and their properties, make colour images from original fits images and simple supernovae LC photometry to get H_0. (90% : Yr 9-10)

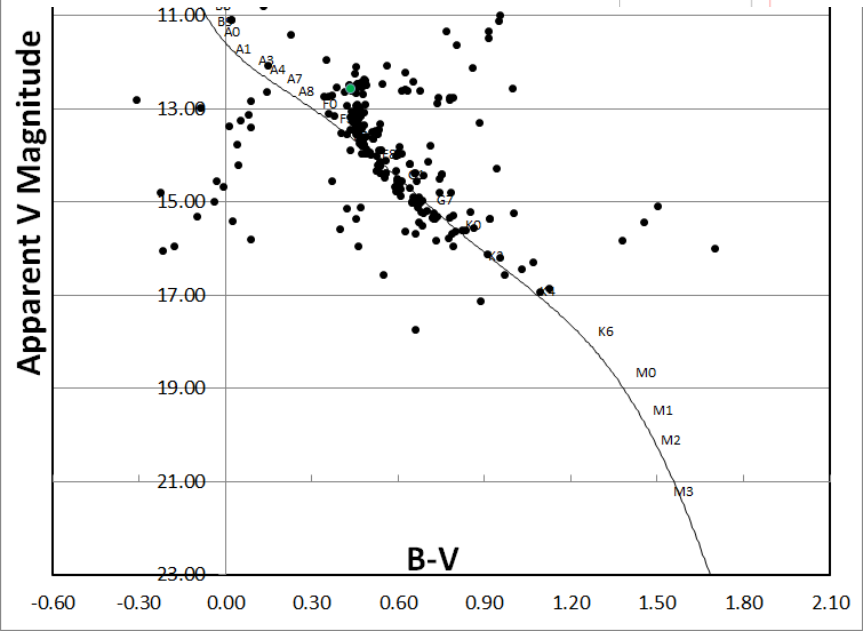


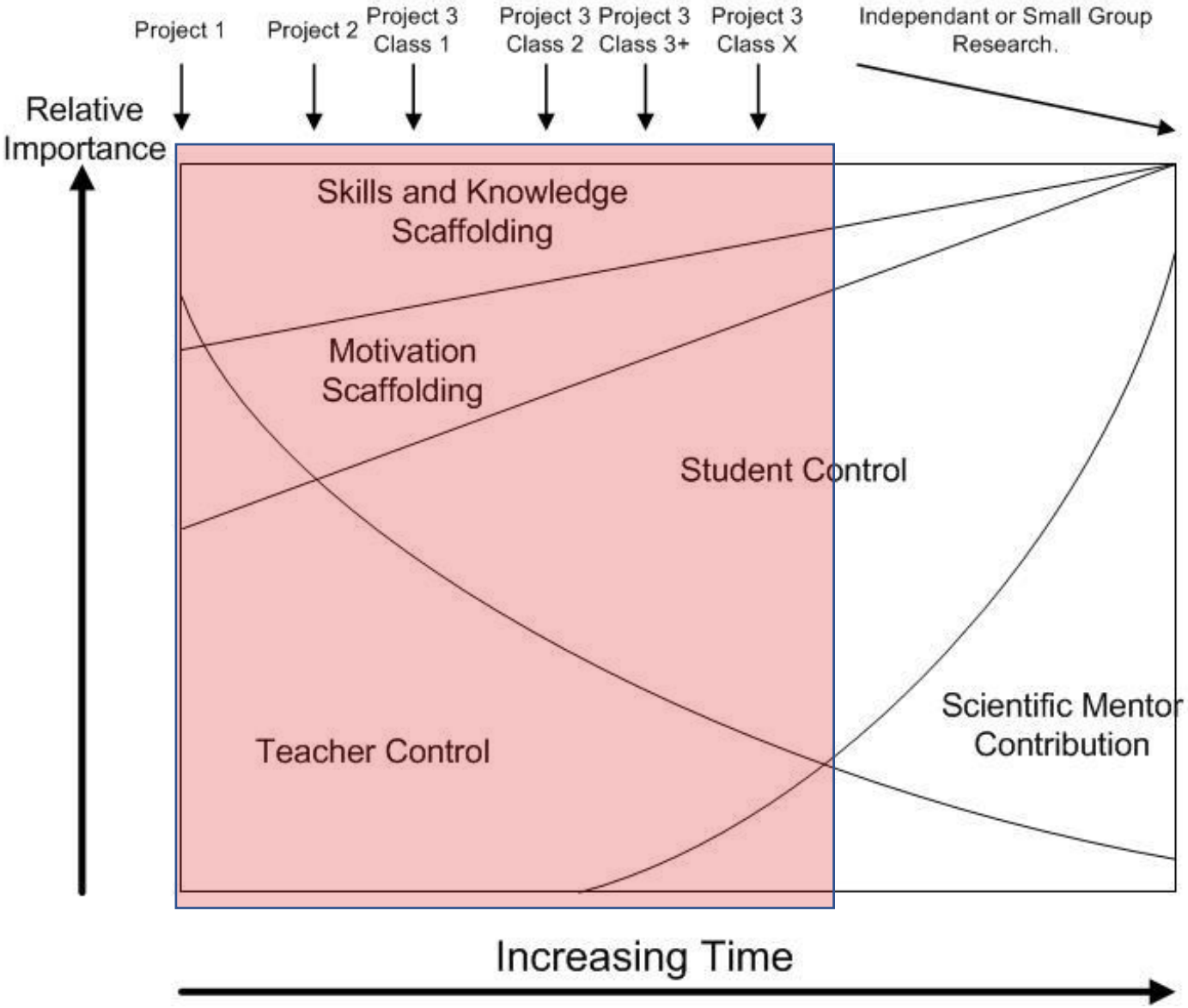




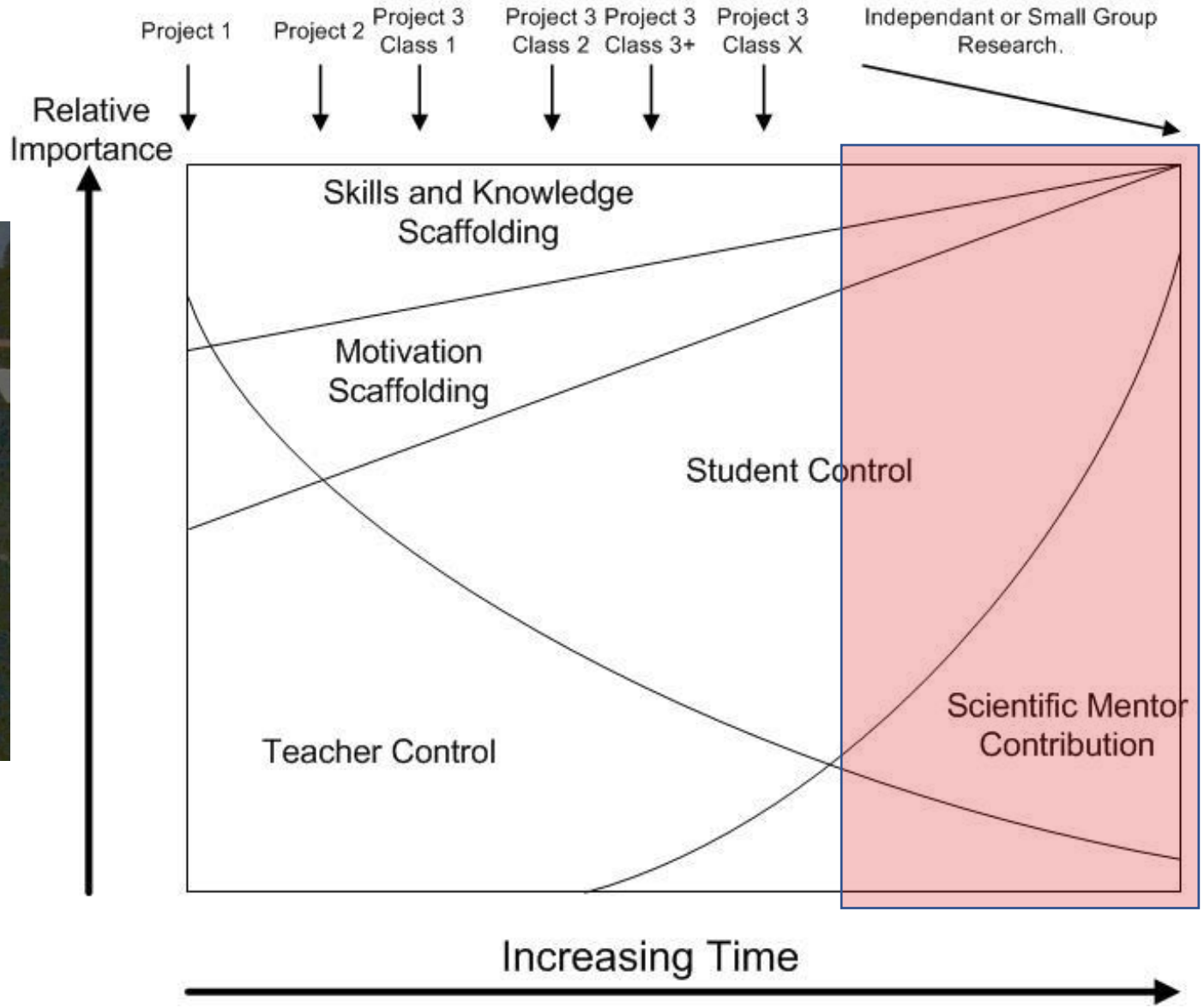
- Some will go deeper in class into star cluster photometry and stellar evolution. (10%: Extended 9/10, 11/12, IB, IRP)







- (≈0%: Some individuals or groups will want to do their own original research.)



The Standard Model.

- Allocate teams or individuals to work on a longer “Science as a Human Endeavour” presentation to research an allocated person/group and event in science history for sociocultural context as well as how science works.
- What are telescopes? Why does their size matter? Why are some images from telescopes blurry and others not?
- What are some of the major “pretty” objects out there in the universe?
- Where are these “pretty” objects in the night sky and why?
- Using images collected from LCO, how do we construct a colour image? What is an image, how is it constructed and what is ‘colour’?
- How do the size, shape and colour of galaxies differ?
- How do we measure the distance to a galaxy? Measuring the distance to M101 using simple photometry of a single supernova (sn2011fe).
- How do we measure the expansion of the universe? Measuring the distance to multiple galaxies using supernovae to create a Hubble Plot and estimate the age of the universe.
- Hold the presentation class about the various people/groups and major events followed by a reflection on science as a human endeavour.

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Are we meeting our goals?

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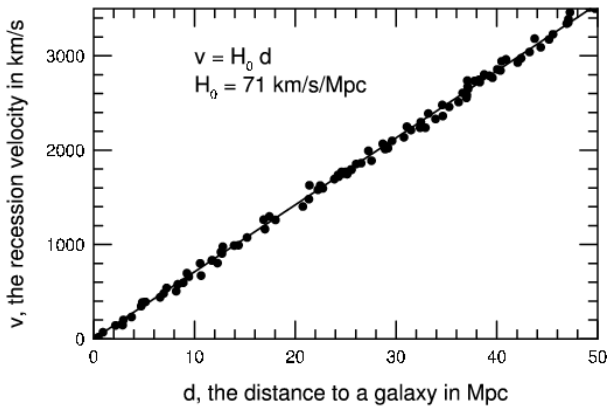

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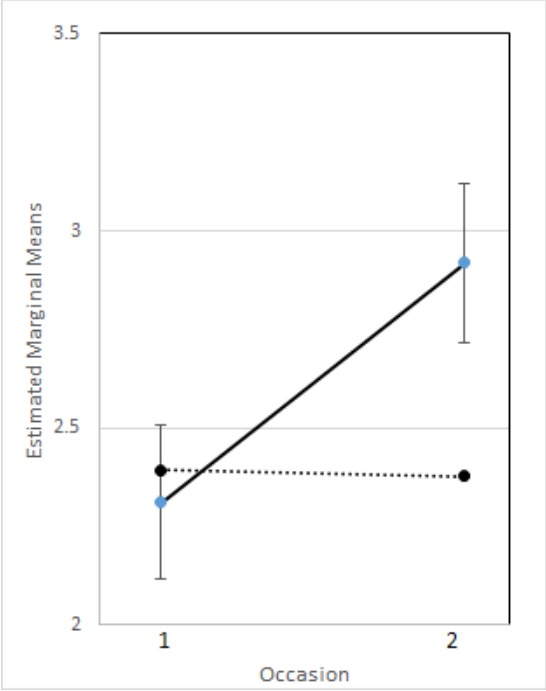
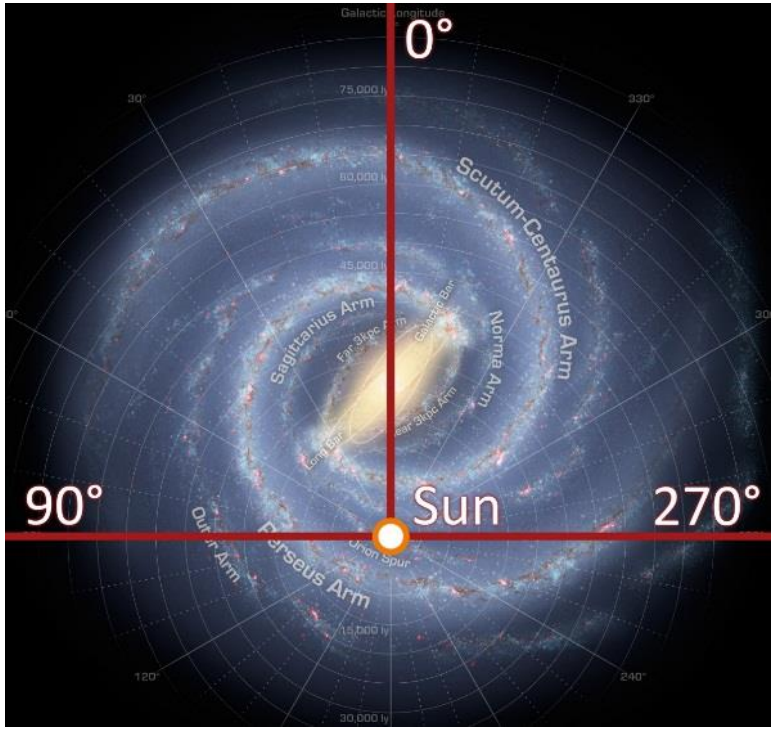
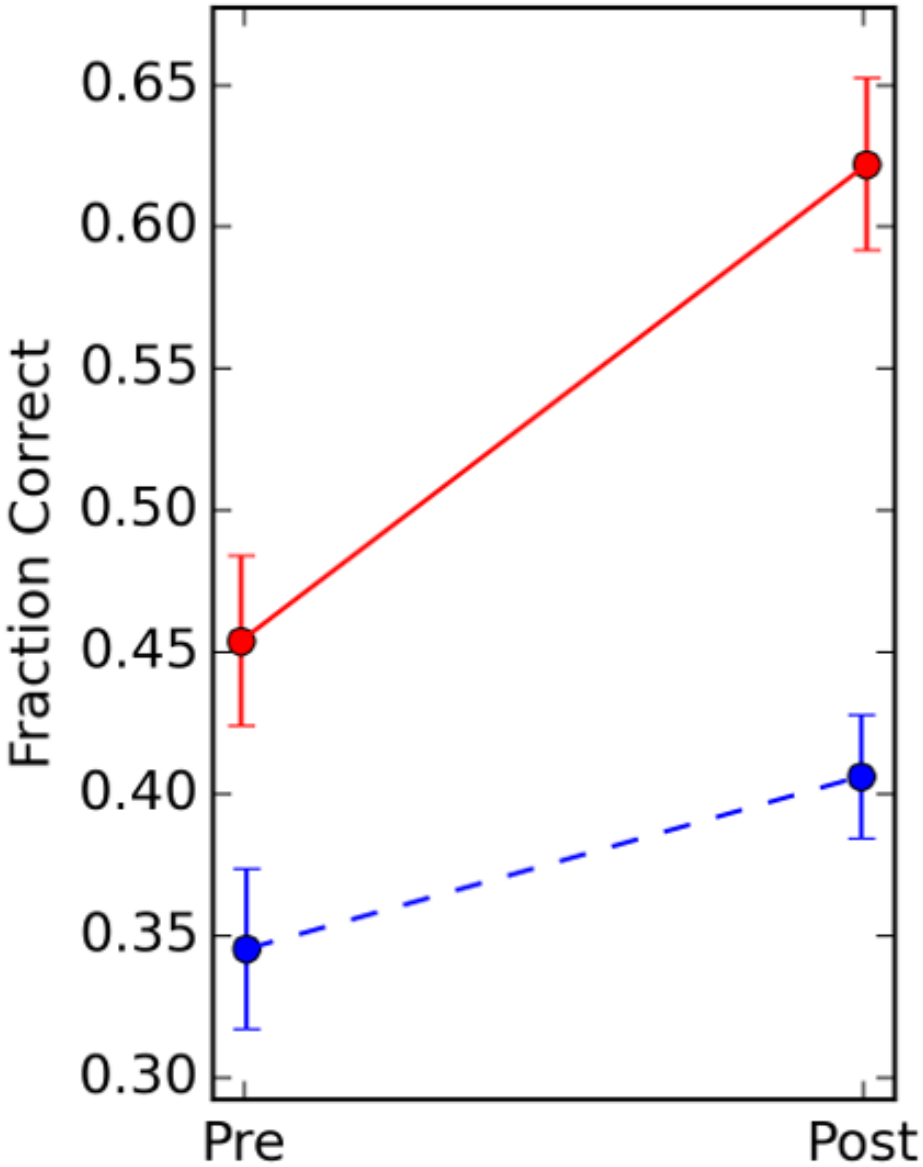
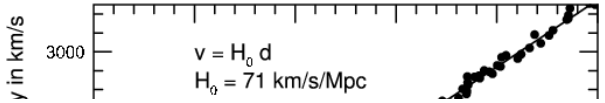
The universe contains features including galaxies, stars and solar systems and the Big Bang theory can be used to explain the origin of the universe (ACSSU188)









Descriptive Statistics	*Mean*	*St.Deviation*	*N*		
Equivalent Pre	45%	17%	31	31%	*Percentage Gain*
Equivalent Post	62%	17%	31	1.01	*Effect Size (Cohen's D)*
Non-Equivalent Pre	35%	16%	31	9%	*Percentage Gain*
Non-Equivalent Post	41%	12%	31	0.44	*Effect Size (Cohen's D)*

*The **Percentage Gain** for each Pre/Post pair is the Actual Gain (Post-Pre) divided by the largest possible gain achievable (100%-Pre). A gain of 100% means that everybody in the class correctly answered all of the questions they got incorrect on the pre-test and got all of the pre-test questions correct again. This is obviously impossible!*
As this Gain is actually an internal property of the survey itself, we are still collecting information on typical values in different contexts so cannot provide a strong guidance as to what is a 'good' gain is as yet. However in similarly constructed surveys, "Traditional" chalk'n'talk classrooms tend to achieve about a 10% gain whilst inquiry-based/flipped/etc. classrooms can range from 25% to 40% and beyond.

*The **Effect Size (Cohen's D)** is a more general estimate of how dramatic the change is.*
A broad introduction is available here : http://rpsychologist.com/d3/cohend/
It compares the difference in the means from the pre to post to their standard deviations.
Roughly speaking 0.2 is a small, 0.5 is a medium, 0.8 is a large and 1.3 is a huge effect size.

Are we meeting our goals?

- Increase students' appreciation for the true methodology and approach of science in contrast to the general, currently poor, students' perceptions of school science.

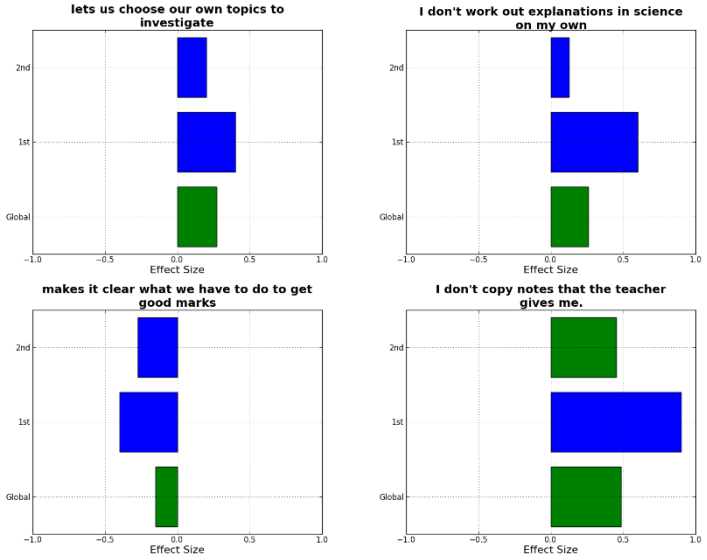
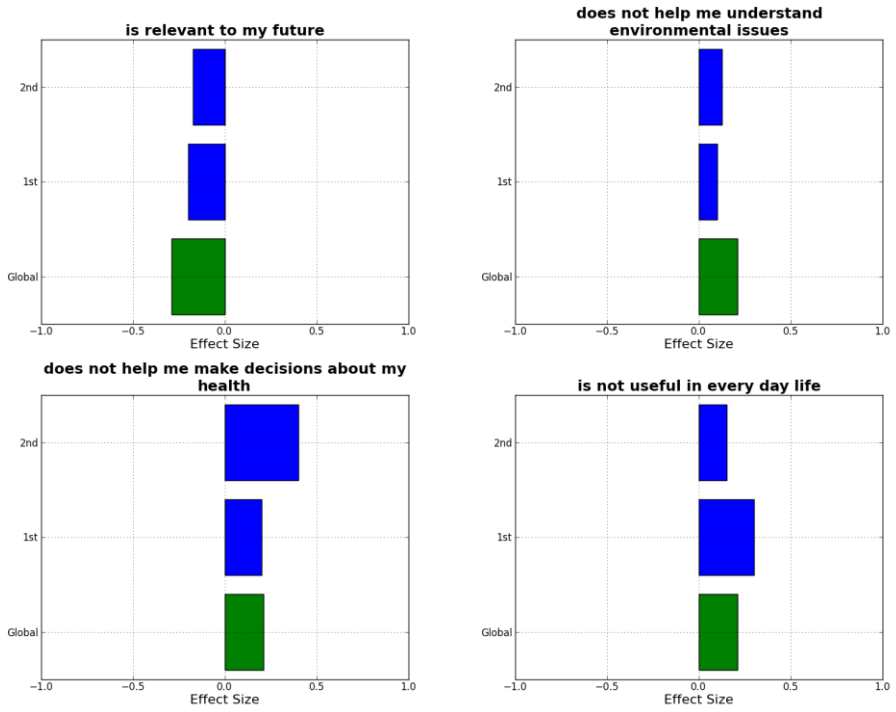


Table 4. Mean values and standard deviation of each attitude measure

	Pre-measure		Post-measure	
Measure	*Mean*	*SD*	*Mean*	*SD*
Learning science in school	3.38	0.82	3.06	0.97
Self-concept in science	3.41	0.70	3.24	0.75
Practical work in science	4.05	0.64	3.95	0.77
Science outside of school	2.75	0.93	2.64	0.92
Future participation in science	2.57	0.85	2.38	0.89
Importance of science	3.58	0.67	3.50	0.65
General attitude towards school	3.40	0.76	3.32	0.77
Combined interest in science	2.92	0.76	2.71	0.83



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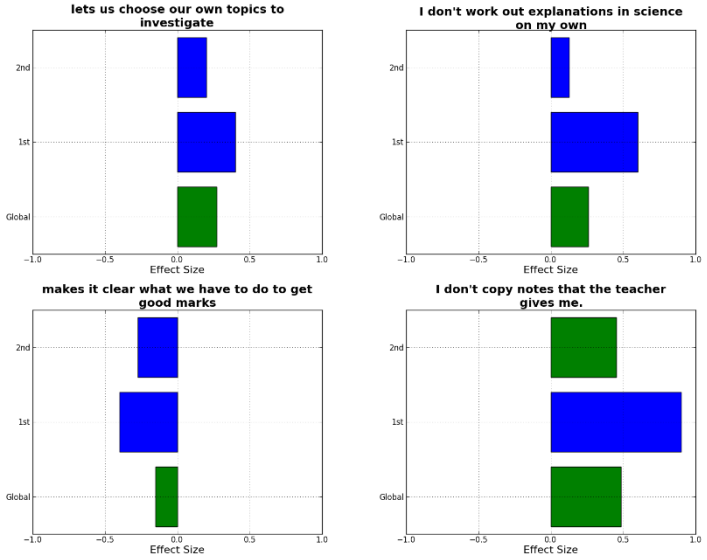
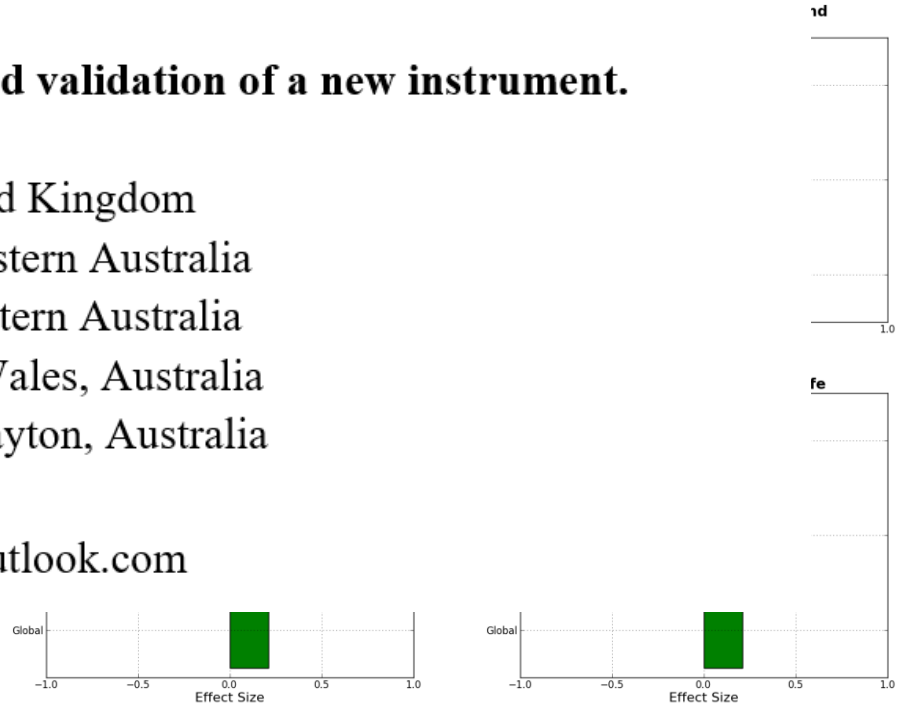


Astronomy and Science Student Attitudes (ASSA): A short review and validation of a new instrument.

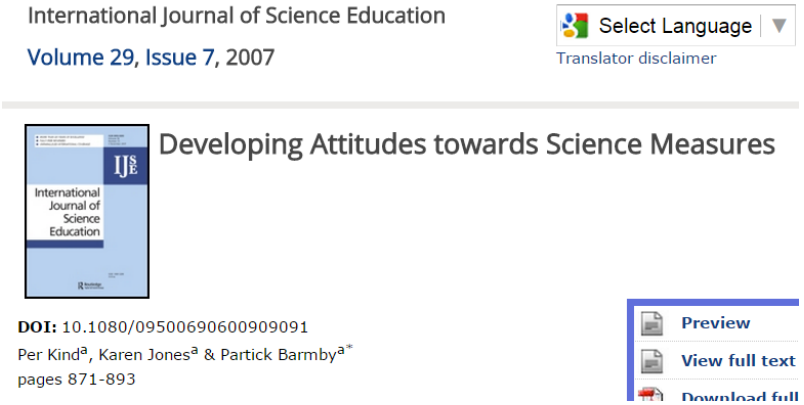
Sophie Bartlett, Cardiff University, Wales, United Kingdom
Michael T. Fitzgerald, Edith Cowan University, Western Australia
David H. McKinnon, Edith Cowan University, Western Australia
Lena Danaia, Charles Sturt University, New South Wales, Australia
Jasmina Lazendic-Galloway, Monash University, Clayton, Australia

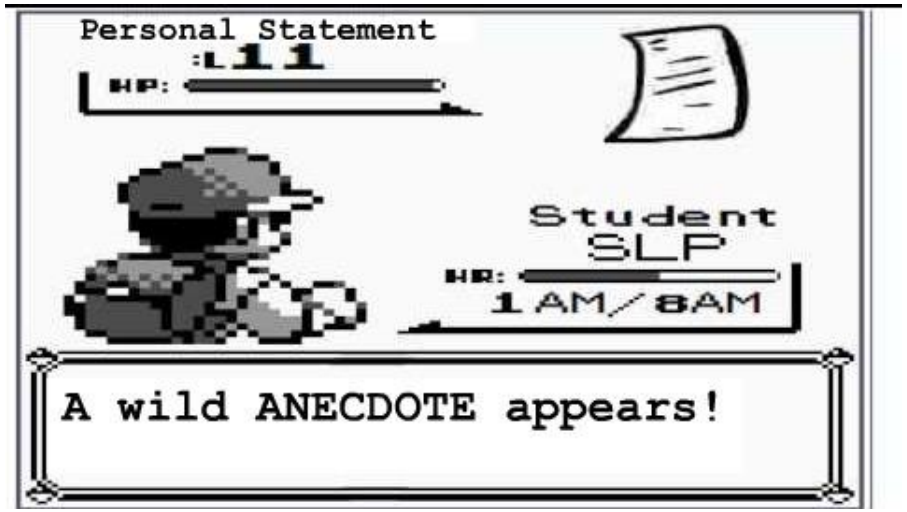
Contact info: Sophie Bartlett, sophie-bartlett@outlook.com



Are we meeting our goals?

- Increase the probability of students choosing science other than as a potential personal interest, as a topic for higher level study or as a potential future career path or, at the very least, help them discover that they *may be* interested in science;





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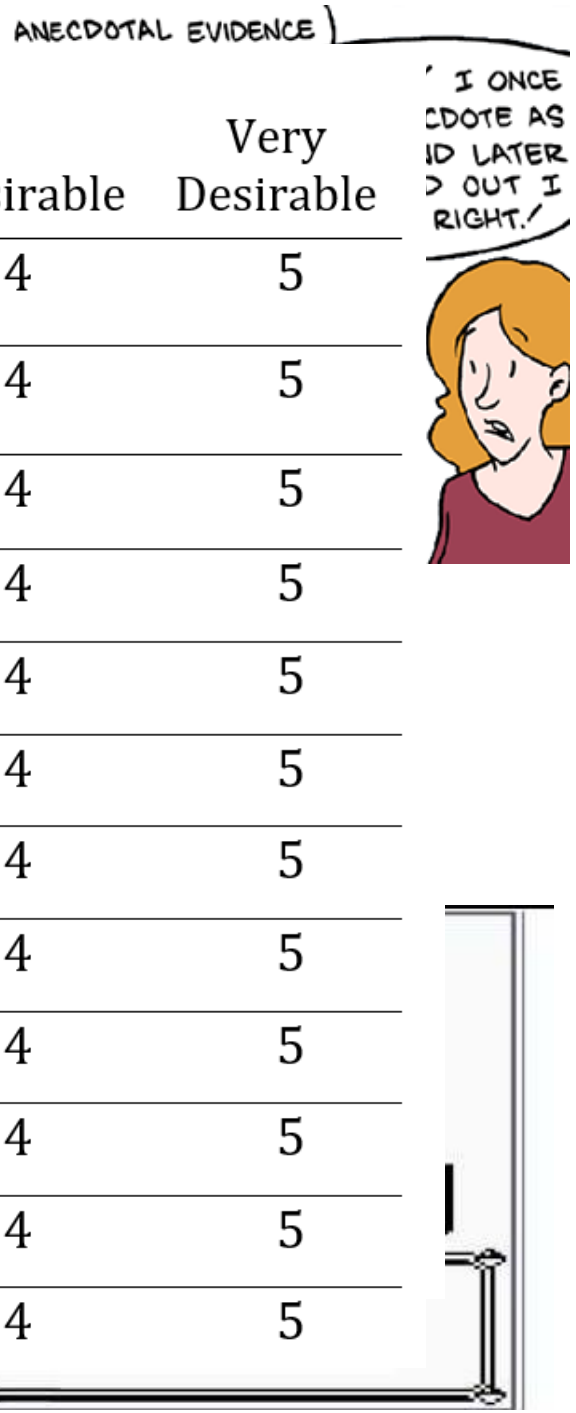
A wild ANECDOTE appears!

How desirable would each of the following careers be to you?	Very Undesirable	Undesirable	Neutral	Desirable	Very Desirable
Medical professional (e.g. doctor, dentist, vet)	1	2	3	4	5
Health professional (e.g. nursing, pharmacy)	1	2	3	4	5
Biologist	1	2	3	4	5
Earth/Environmental scientist	1	2	3	4	5
Astronomer	1	2	3	4	5
Chemist	1	2	3	4	5
Physicist	1	2	3	4	5
Engineer	1	2	3	4	5
Computer Scientist	1	2	3	4	5
Other Scientist	1	2	3	4	5
Mathematician	1	2	3	4	5
Science Teacher	1	2	3	4	5



PHOTOMETRIC AND PROPER MOTION STUDY OF NEGLECTED OPEN CLUSTER NGC 2215

M.T. Fitzgerald[1,2], L. Inwood, D.H. McKinnon[2], W. S. Dias[5,6], M. Sacchi[4], B. Scott, M. Zolinski[7], L. Danaia[4], R. Edwards[7]

The Astronomical Journal

ABSTRACT

Optical UBVRI photometric measurements using the Faulkes Telescope North were taken in early 2011 and combined with 2MASS JHK$_s$ and WISE infrared photometry as well as UCAC4 proper motion data in order to estimate the main parameters of the galactic open cluster NGC 2215 of which large uncertainty exists in the current literature. Fitting a King model we estimate a core radius of 1.12′±0.04′ (0.24±0.01pc) and a limiting radius of 4.3′±0.5′ (0.94±0.11pc) for the cluster. The results of isochrone fits indicates an age of $log(t) = 8.85 \pm 0.10$ with a distance of $d = 790 \pm 90$pc, a metallicity of $[Fe/H] = -0.40 \pm 0.10$ dex and a reddening of $E(B-V) = 0.26 \pm 0.04$. A proportion of the work in this study was undertaken by Australian and Canadian upper secondary school students involved in the Space to Grow astronomy education project, and is the first scientific publication to have utilized our star cluster photometry curriculum materials.

Subject headings: Methods: observational — open clusters and associations : general — open clusters and associations : individual (NGC 2215) — Techniques: photometric

Publications of the Astronomical Society of Australia, 2012, **29**, 72–77
http://dx.doi.org/10.1071/AS11046

RR Lyrae Stars in the Globular Cluster NGC 6101

M. T. Fitzgerald[A,B,F], *J. Criss*[C], *T. Lukaszewicz*[C], *D. J. Frew*[A,B], *M. Catelan*[D], *S. Woodward*[C], *L. Danaia*[E], *and D. H. McKinnon*[E]

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[E]Charles Sturt University, Bathurst, NSW 2795, Australia
[F]Corresponding author. Email: mfitzasp@gmail.com

Abstract: *V*- and *I*-band observations were taken over 9 months to study the RR Lyrae population poor diffuse globular cluster NGC 6101. We identify one new variable, which is either a potential red giant variable or eclipsing binary, and recover all previously identified RR Lyraes. One previo RR Lyrae is reclassified as an RRc type, while two period estimations have been significantly confirm that NGC 6101 is Oosterhoff type II with a high ratio of $n(c)/n(ab+c) = 0.833$ with a ver

- Involve the nontrivial use of real astronomical data from a real research grade telescope;
- **Enable students, or a smaller subset that so desire, to take their research to a natural scientific conclusion in the form of a scientific publication.**

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Inquiry-Based Educational Design for Large-Scale High Schoo
Telescopes

Fitzgerald, Michael T. and McKinnon, David H. and Danaia, Lena J. (2015) *Inquiry-Based School Astronomy Projects Using Real Telescopes.* Journal of Science Education and Te
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Abstract

In this paper, we outline the theory behind the educational design used to implement a la
project. This design was created in response to the realization of ineffective educational
The new design follows an iterative improvement model where the materials and genera
feedback. The improvement cycle concentrates on avoiding overly positive self-evaluatio
and community factors while concentrating on backward mapping from clearly set goals.
support and the potential for failure in the classroom, are dealt with as much as possible

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