



TEACHING SUSTAINABLE CHEMISTRY: ESCAPING FROM GREEN

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SETTING THE SCENE

- Pair Up
- Decide who is person 'A' and who is person 'B'
- A word will appear on the screen. Person 'A' should talk about it for 25 seconds
- Another word will appear, person 'B' should talk about it.
- And so on...

POLLUTANT

PERSON A – 25 SECONDS!



TOXIC

PERSON B – 25 SECONDS!

CHEMISTRY

PERSON A – 25 SECONDS!

CHEMICAL

PERSON B – 25 SECONDS!

GREEN CHEMISTRY

PERSON A – 25 SECONDS!

SUSTAINABLE CHEMISTRY

PERSON B – 25 SECONDS!

GREEN

“Paul Anastas and John C. Warner co-authored the groundbreaking book, **Green Chemistry: Theory and Practice** in 1998. The **12 Principles of Green Chemistry** outlined within this work declared a **philosophy** that motivated academic and industrial scientists at the time and continues to guide the **green chemistry movement**.”

Green Chemistry Pocket Guide

The 12 Principles of Green Chemistry

Provides a framework for learning about green chemistry and designing or improving materials, products, processes and systems.

1. Prevent waste
2. Atom Economy
3. Less Hazardous Synthesis
4. Design Benign Chemicals
5. Benign Solvents & Auxiliaries
6. Design for Energy Efficiency
7. Use of Renewable Feedstocks
8. Reduce Derivatives
9. Catalysis (vs. Stoichiometric)
10. Design for Degradation
11. Real-Time Analysis for Pollution Prevention
12. Inherently Benign Chemistry for Accident Prevention

www.acs.org/greenchemistry



<https://www.acs.org/content/acs/en/greenchemistry/what-is-green-chemistry>

COURSE BACKGROUND

- 'Traditional' Keele Chemistry Course before 2011/12
- Dual Honours, Major Route
- Major curriculum redesign starting with 2012/13 intake:
- redevelop every module
- create Single Honours Route (Est. 2013 for 2nd year entry)
- create new modules
- Create UG Masters (MChem, Est. 2015 for 3rd year entry)

2ND YEAR SINGLE HONOURS MODULE 13/14

- Whole year 15-credit module, no exam, focus on developing transferrable skills hand-in-hand with chemistry knowledge.
- Several aspects taught through narratives.
- Disjointed list of topics:
 - - polymer chemistry
 - - environmental chemistry
 - - industrial chemistry
 - - chemistry of gadgets

A MOMENT OF FLIPPANCY...

- ...and we called it
- ‘Sustainable Chemistry’.
- It was a ‘theme’ for the module.
- Then we had no option but to ‘do’ Sustainable ‘stuff’.



SUSTAINABLE CHEMISTRY MODULE EST. 2013

13/14: 2nd year module. 17 students

14/15: Industrial Chem, 2nd year (14/15 18 students, 15/16 38 students, 16/17, 56 students)

14/15: 1st & 2nd year. 34 students

15/16: 1st & 2nd year.
70 students (Keele),
34 students (NXU - distance learning)

16/17: 1st & 2nd year.

80 students (Keele), 34 students (NXU - distance learning)

SUSTAINABLE/INDUSTRIAL ARC

- total emphasis on 'non-exam' assessment
 - written, graphical, and oral presentation skills
 - group work, reflection on skills
 - essays, professional reports
- link to Graduate Attributes

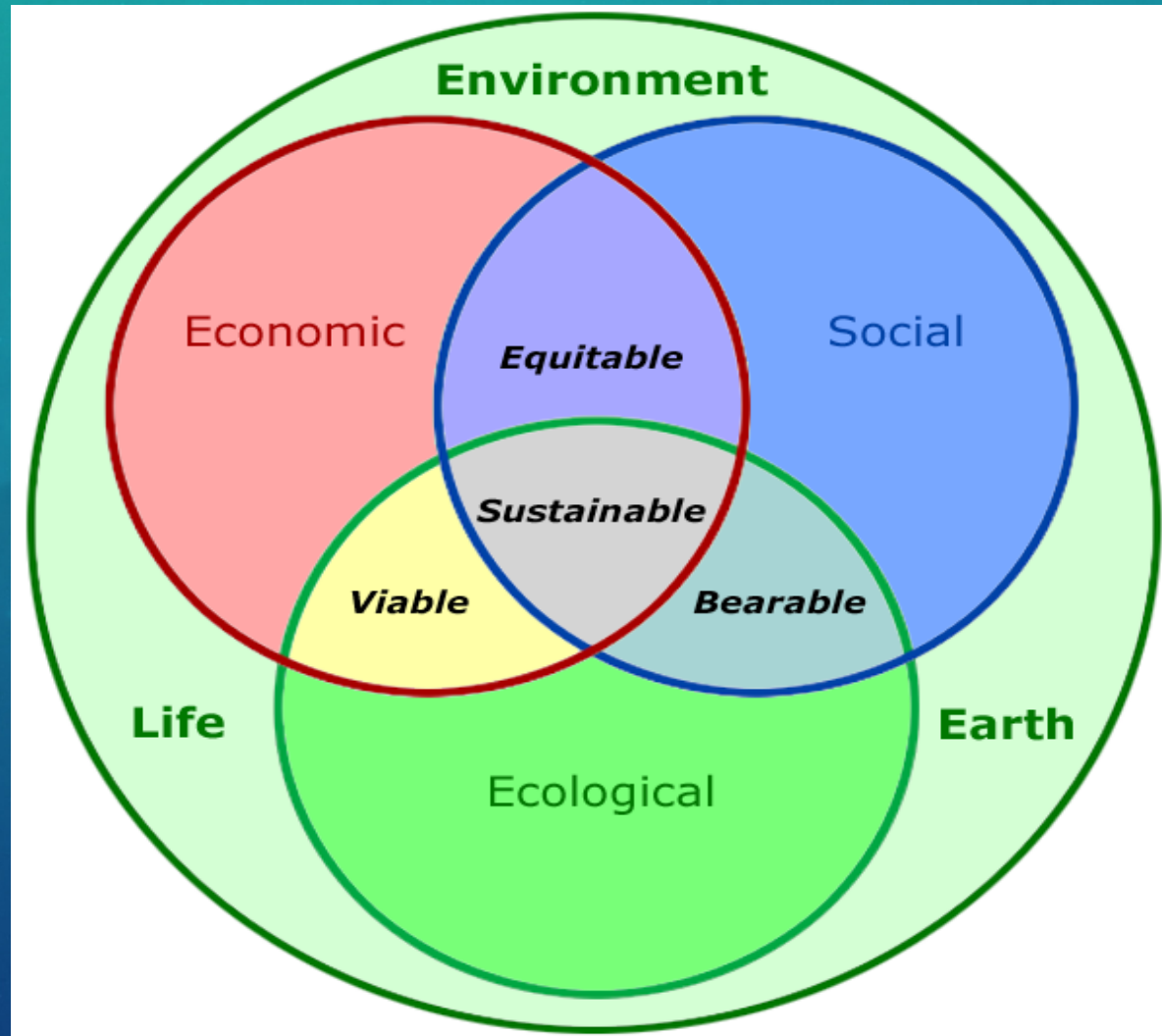
WHAT DO THE STUDENTS THINK THEY ARE GETTING?

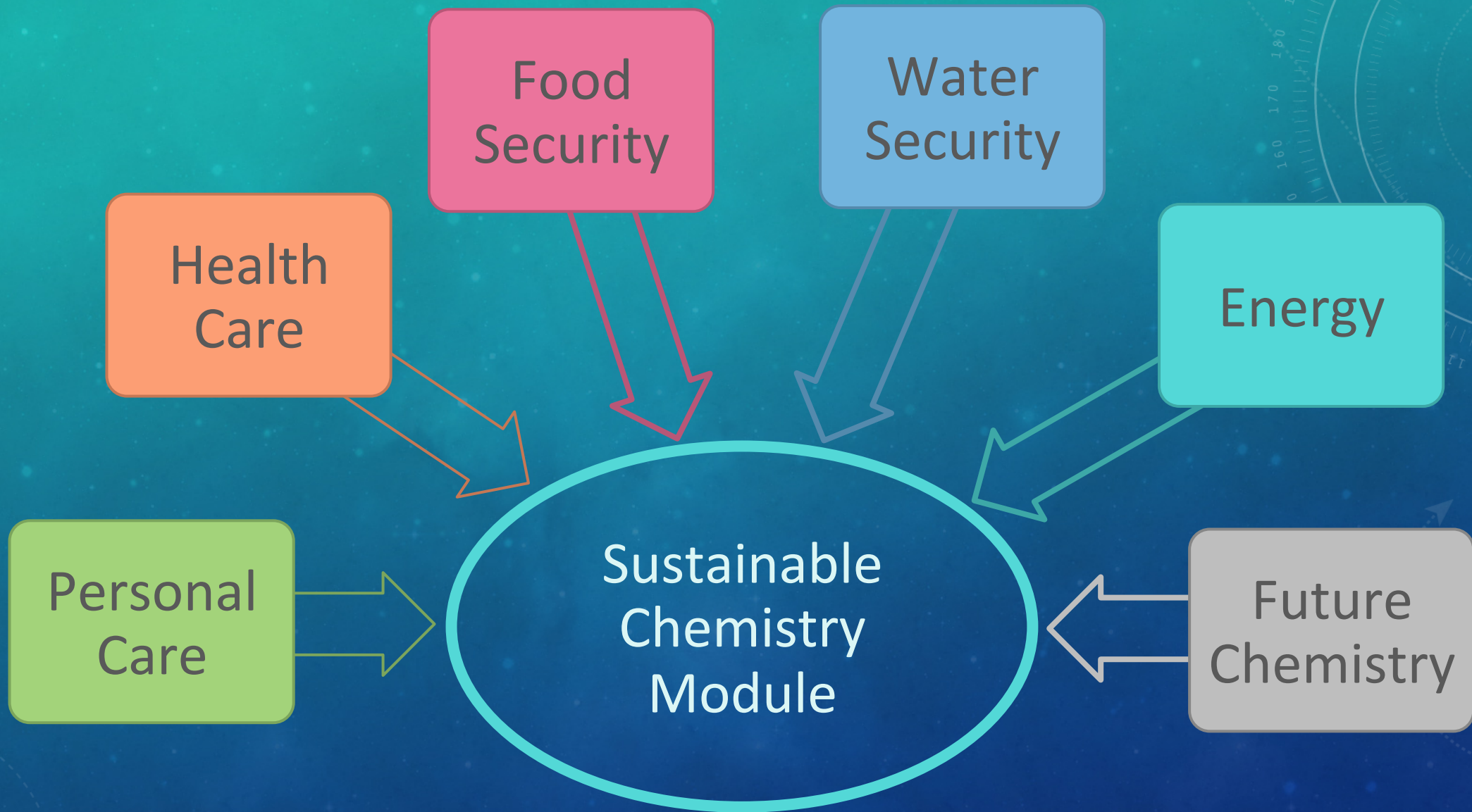
Extremely relevant	Probably important	Hmmm, not sure
Chemical Feedstocks (petrochemicals)	Poverty	Nuclear proliferation
Recycling	e-waste	Vegetarianism
Chemical Waste	emerging diseases	Famine
Energy	Chemical Feedstocks (plants)	Gender equality
Global Warming	Antibiotic Resistance	Social housing
Fossil Fuels	Safe drinking water	Terrorism
Pollution	Conservation	
Climate Change		

TOPICS COVERED IN SUS CHEM & INDUSTRIAL CHEM

Extremely relevant	Probably important	Hmmm, not sure
Chemical Feedstocks (petrochemicals)	Poverty	Nuclear proliferation
Recycling	e-waste	Vegetarianism
Chemical Waste	emerging diseases	Famine
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Fossil Fuels	Safe drinking water	Terrorism
Pollution	Conservation	
Climate Change		

CHEMISTRY PERSPECTIVE





MODULE DESIGN (15/16 – IN PERSON AND DISTANCE)

- Keele University (KU)
- [face-to-face]
- 12 x 2 hour workshops
- 5 online tasks (35%)
- 2 essays (50%)
- 1 magazine (15%)
- Nanjing XiaoZhuang University (NXU)
- [distance]
- 10 topics
- 5 online tasks (30%)
- 1 essay (50%)
- 1 video (20%)

INTERNATIONAL GROUP WORK

- groups of NXU and KU students: 5 – 6 students per group
- identical assessment guidelines, different submission methods
- vague suggestions for topics, encouraged to just chat
- exchange emails
- 10% of module mark; KU: 48/59 , NXU: 34/37 students submitted

*“I didn't like this task!!
Because the Keele students
didn't email me more!!!” -
NXU Student*

*“The assignment was
completely pointless as
nobody from China replied.” -
KU Student*

EMAILS ON DEADLINE DAY

The Chinese Students
haven't responded to
my email

When did you
send it?

Last night

*&%\$£

“The main surprise was the time difference between the 2 countries as it was about 8 hours meaning that the conversations were often stop start, which was weird to me as at first it didn't really click to me that I was speaking to people half way around the world about the same chemistry course from the same lecturers.”

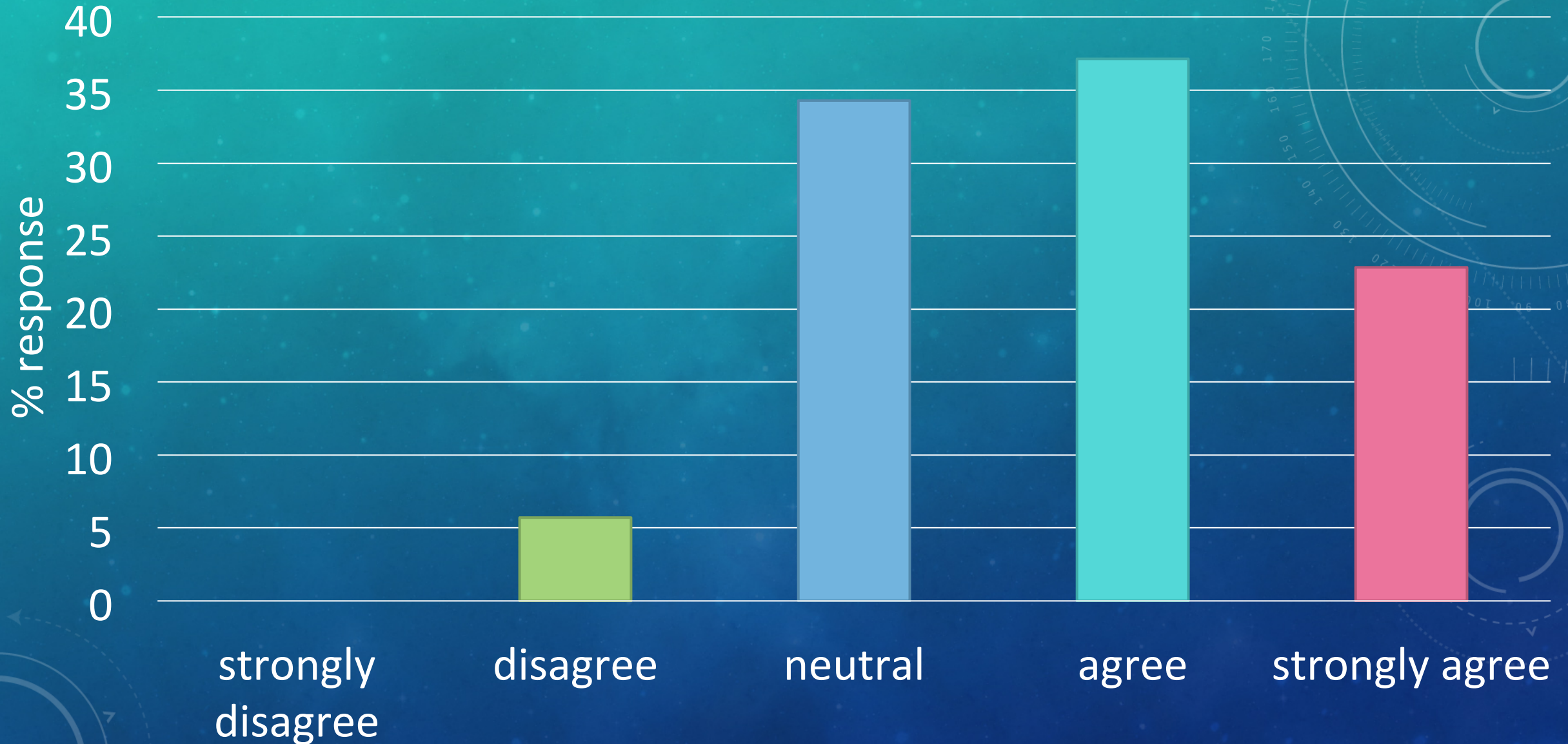
“Be more nice and open, don't be shy, be willing to chat to others.”

“It's already very good. It's interesting. The problem is some of the students in my group didn't talk with each other.”

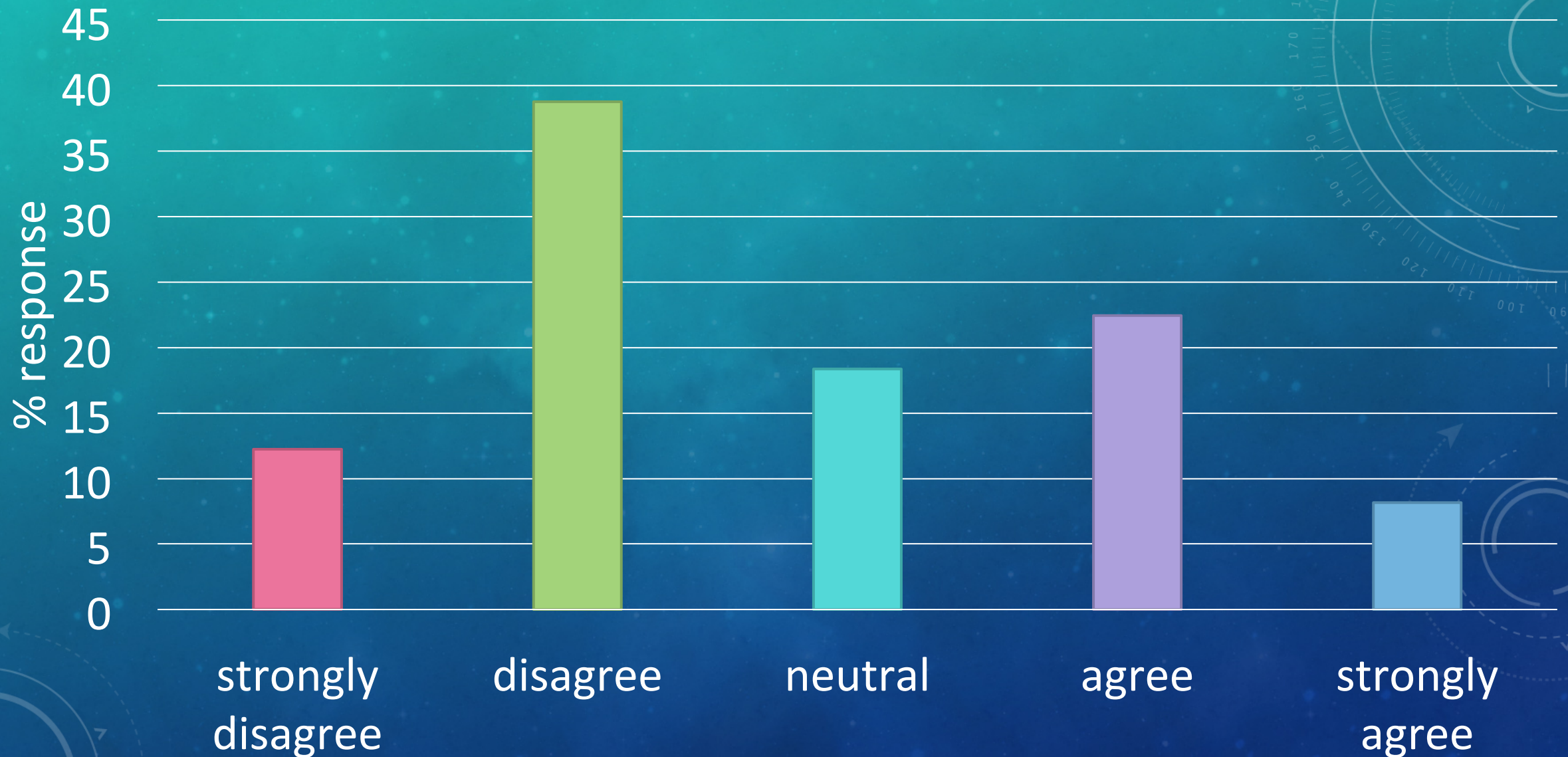
“It was nice to converse with the Chinese students and to find out about how another culture tackles sustainability.”

“I'd just like to say how nice it was that Xinyu was so enthusiastic about talking to people from another country and it was a pleasure talking to him, he even told me his favourite actor is Daniel Craig.”

NXU: Emailing the Keele Students was Interesting



KU: Most of my group responded to emails.

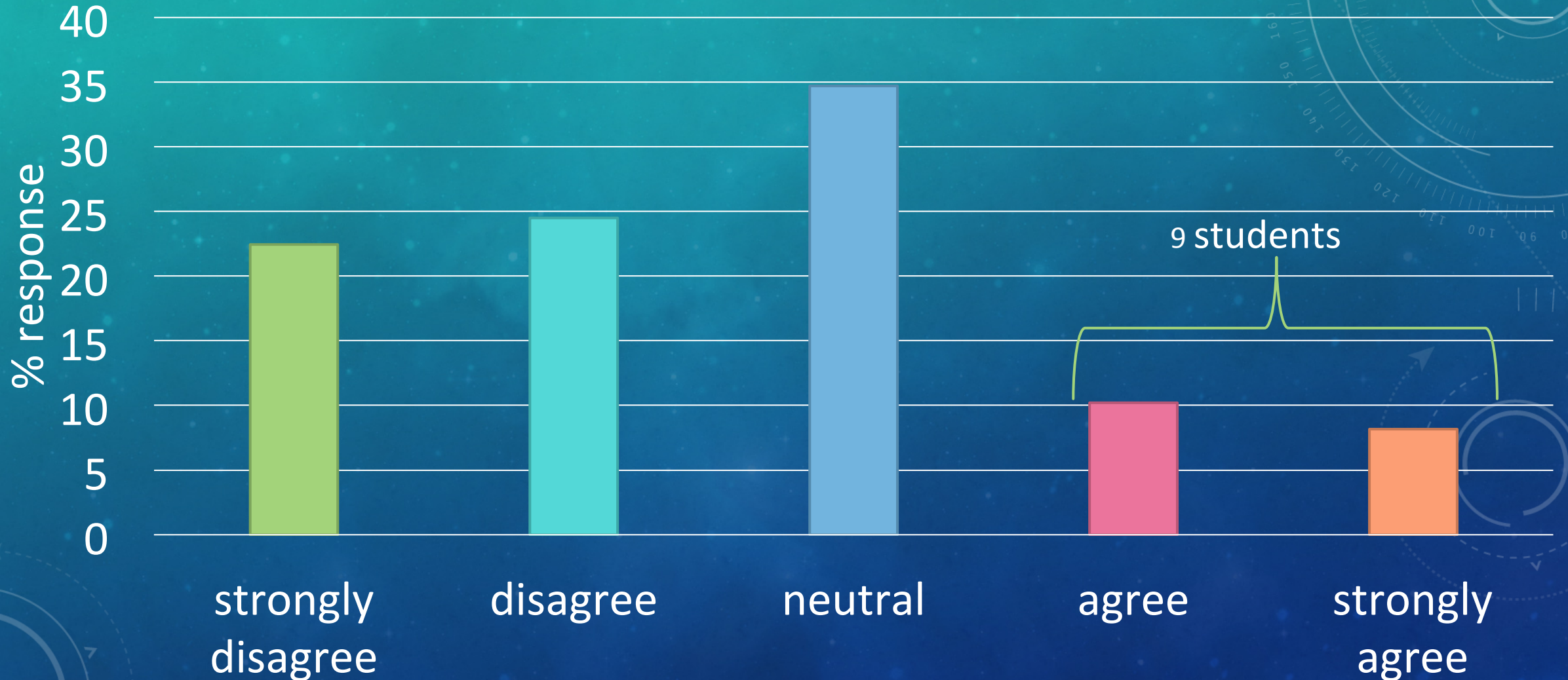


YOU CAN'T WIN...

“The fluency of my groups English is astounding, rarely did we have a communication barrier due to language. Also, the Teletubbies are very popular in China!”

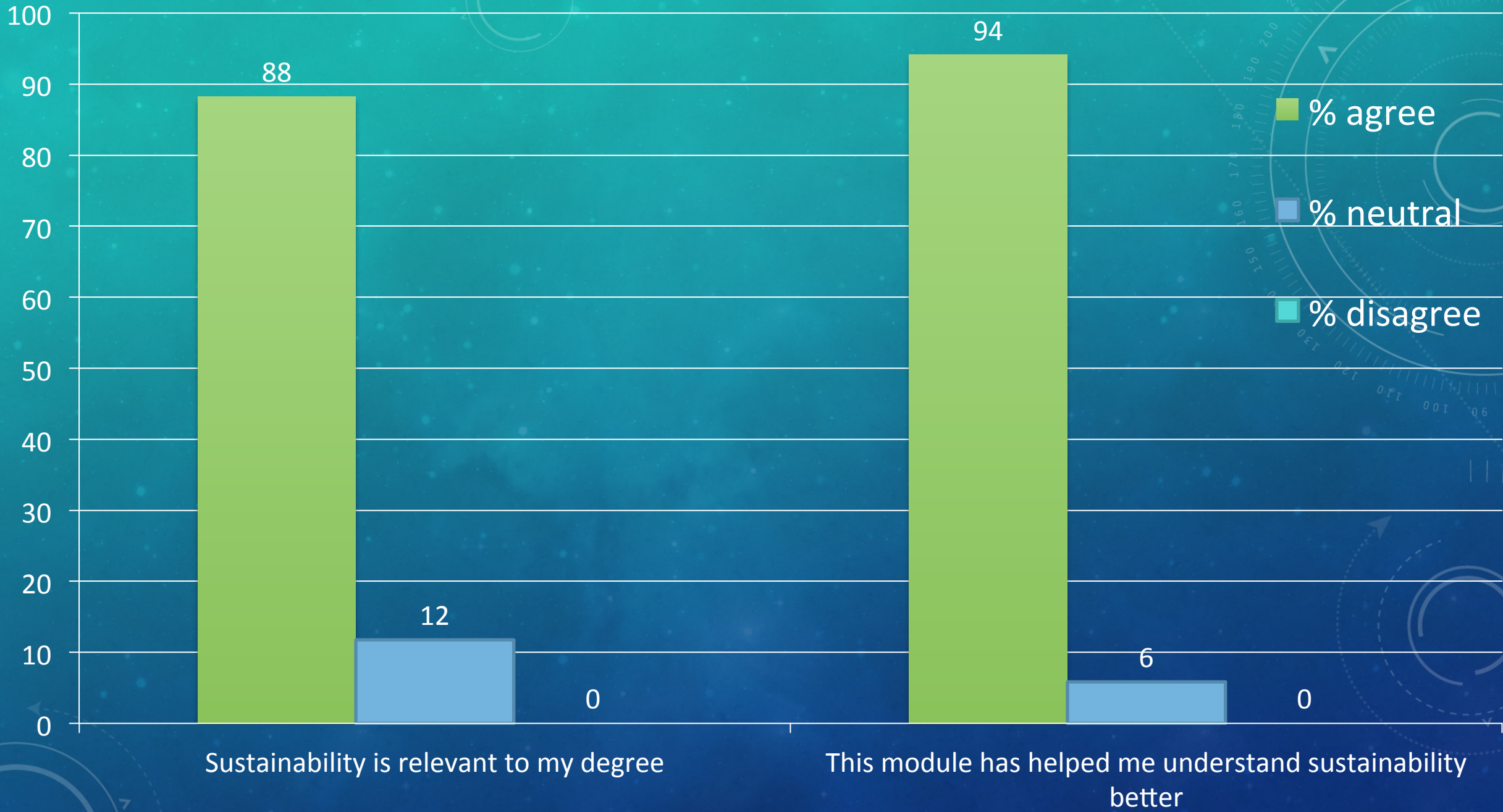
“The language barrier was hard to overcome, not that I can speak any Chinese but it made it hard to ask and have answered in depth question.”

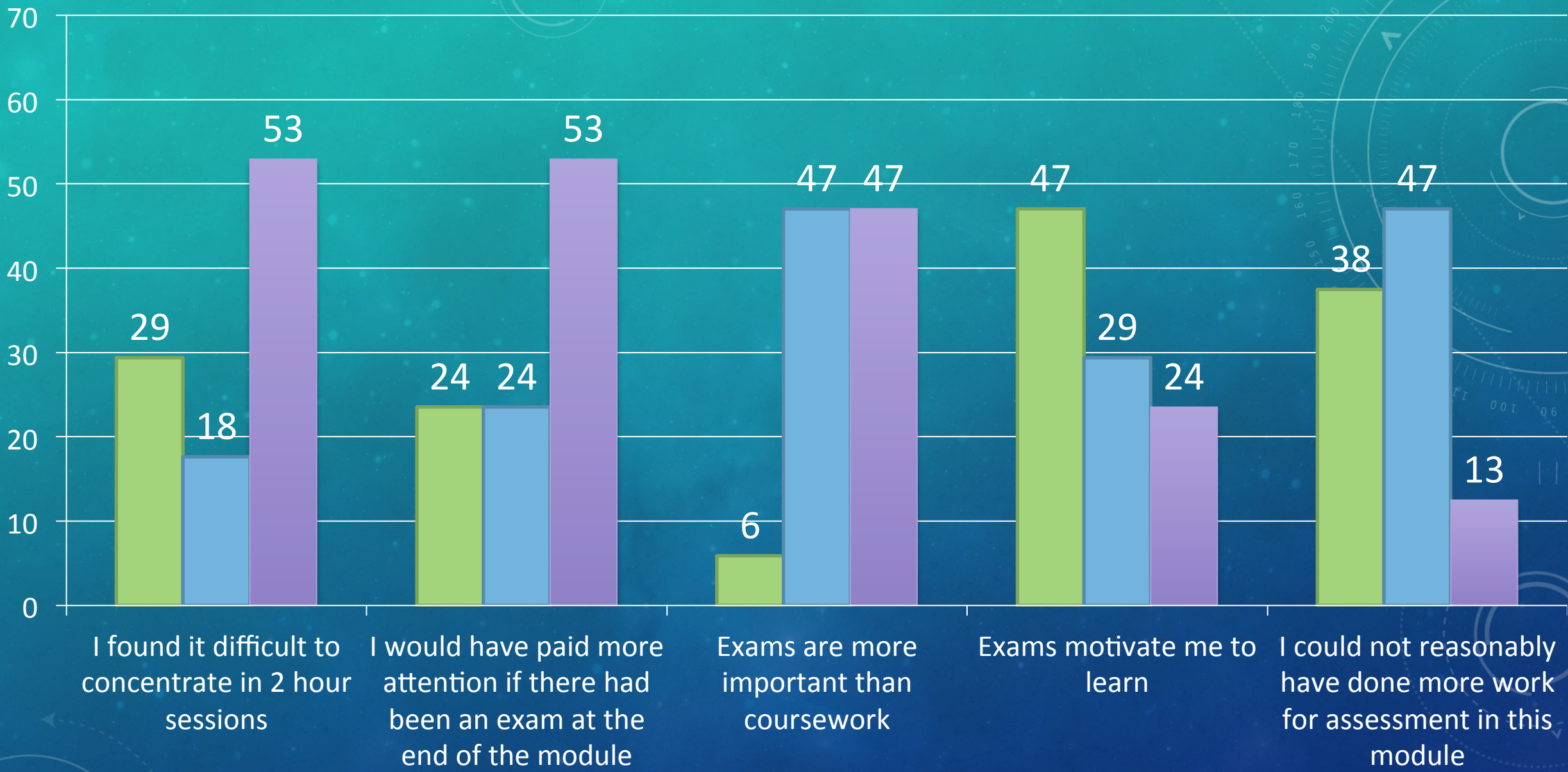
KU: I will keep in touch with Chinese students from my group.



GENERAL MODULE EVALUATION

The background features a gradient from teal at the top to dark blue at the bottom, with a fine, light-colored particle or dust effect. On the right side, there are several faint, semi-transparent circular elements. The most prominent is a large circular gauge or scale with numerical markings from 80 to 200 and a central circular arrow. Other smaller circular patterns with arrows are scattered throughout the background.





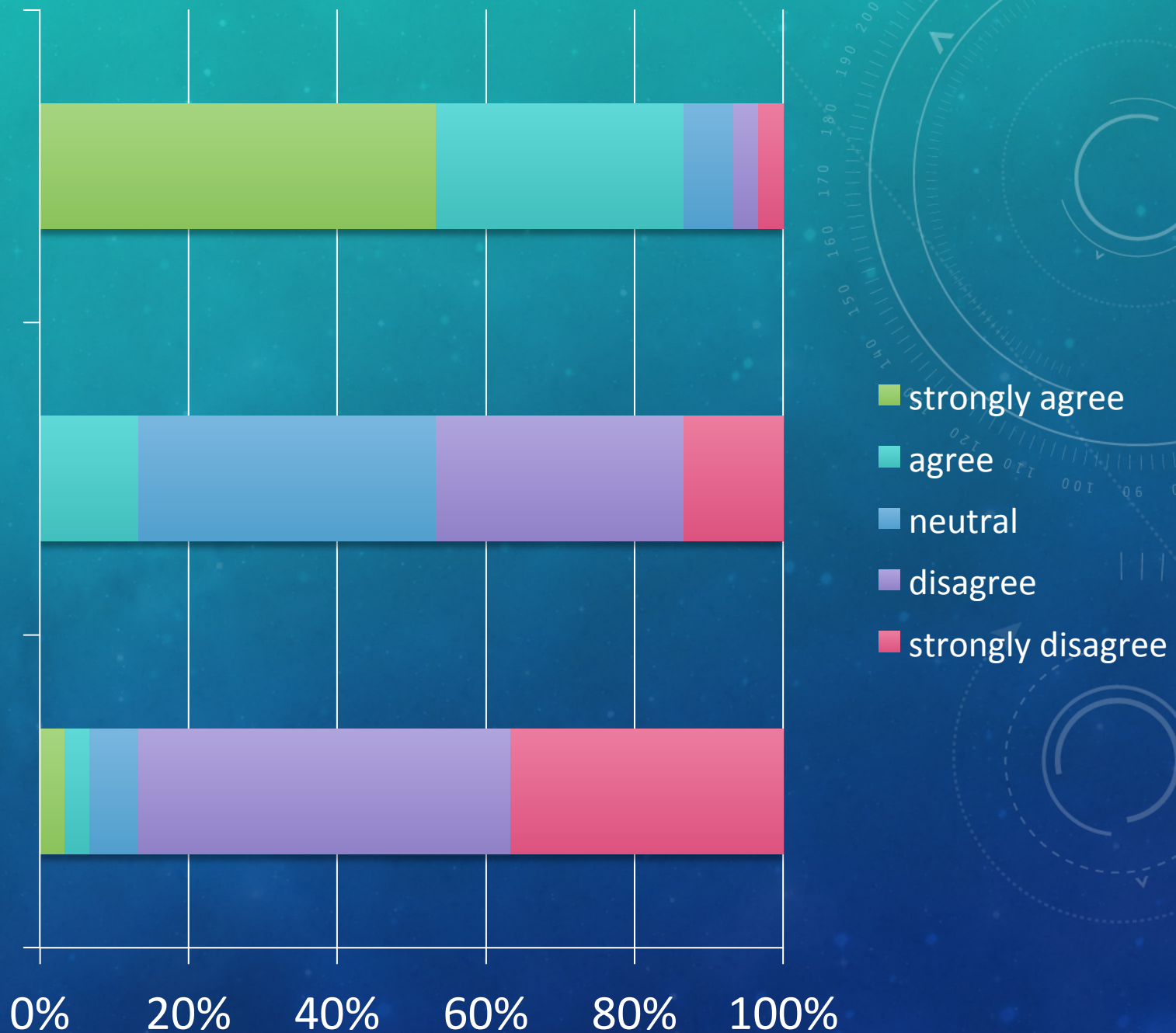
POTENTIAL RESEARCH QUESTIONS

- What do students know from 'before' uni about sustainability?
- Is there any shift in attitude throughout the module?
- What else should we be embedding within the module?

Chemistry research can solve many problems faced by humanity.

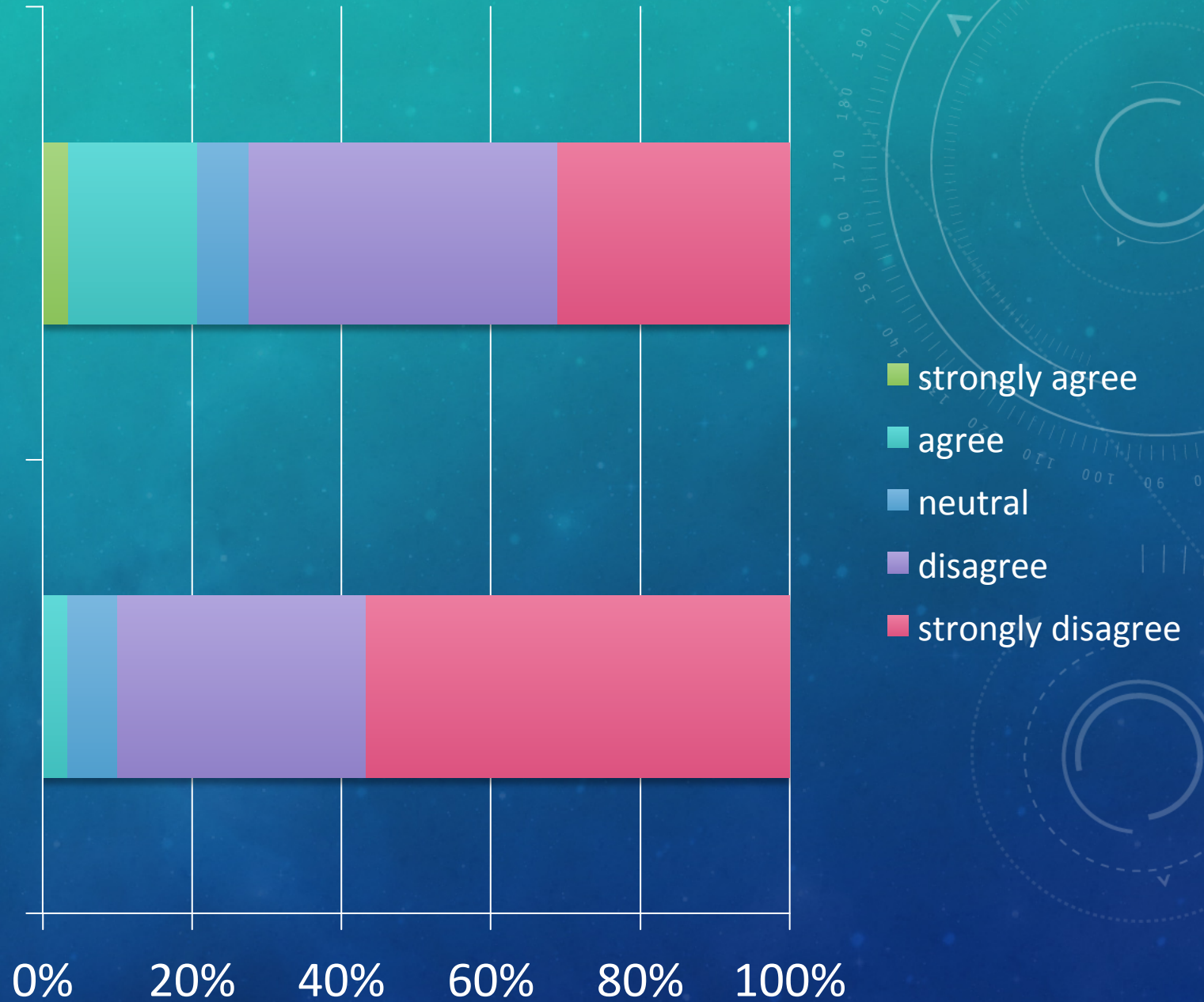
My comfort and well-being are more important than environmental considerations.

Sustainability is not relevant to my life.



As a student, there is no more I can do to live more sustainably

Anthropogenic (caused by humans) climate change is a myth.



PLEASE DEFINE SUSTAINABILITY

- “keeping present situations the same/constant”
- “sustainability is the maintenance of resources”
- “the conservation of optimal conditions”
- “consuming resources, which will last and keep on going, ultimately which will not destroy the planet”
- “sources of energy/materials that will not run out or will still be available for many 100s of years”
- “the ability to maintain a level of resources while still using a resource indefinitely”



CAN 'SUSTAINABILITY' OR 'GREEN' CHEMISTRY BE
SUCCESSFULLY EVALUATED BY STUDENTS WHO CAN'T
DEFINE CHEMICAL?

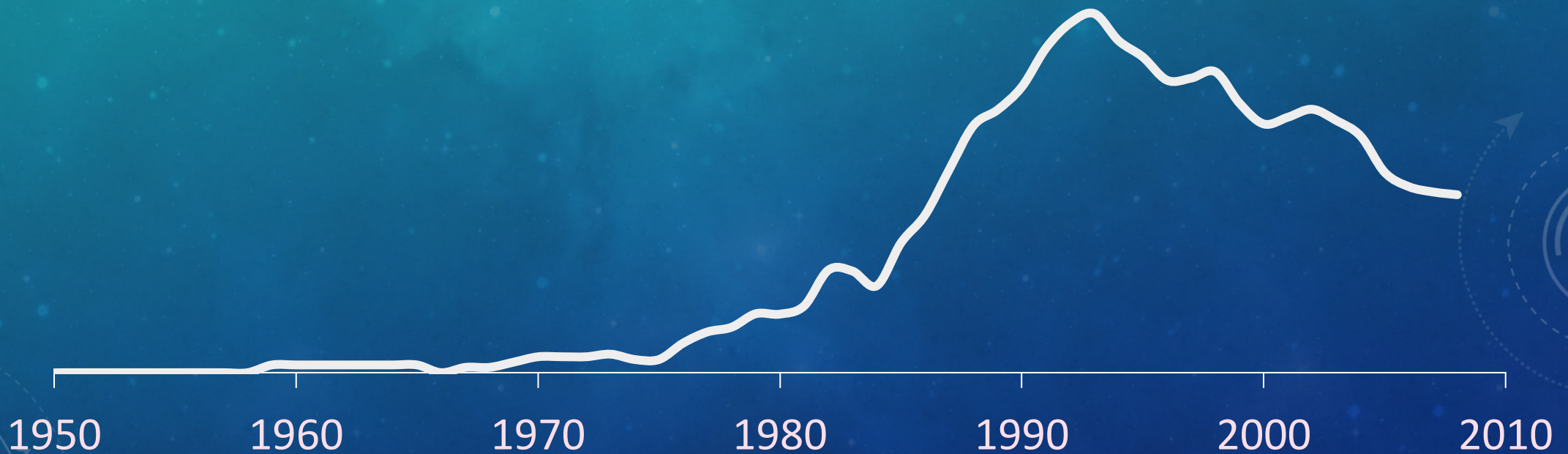
“Poison is in everything, and no thing is without poison. The dosage makes it either a poison or a remedy.”

Paracelcus

Does it?

DOES 'CHEMOPHOBIA' EXIST?

- Frequency of 'chemophobia' in books
- SOURCE: Google ngram viewer

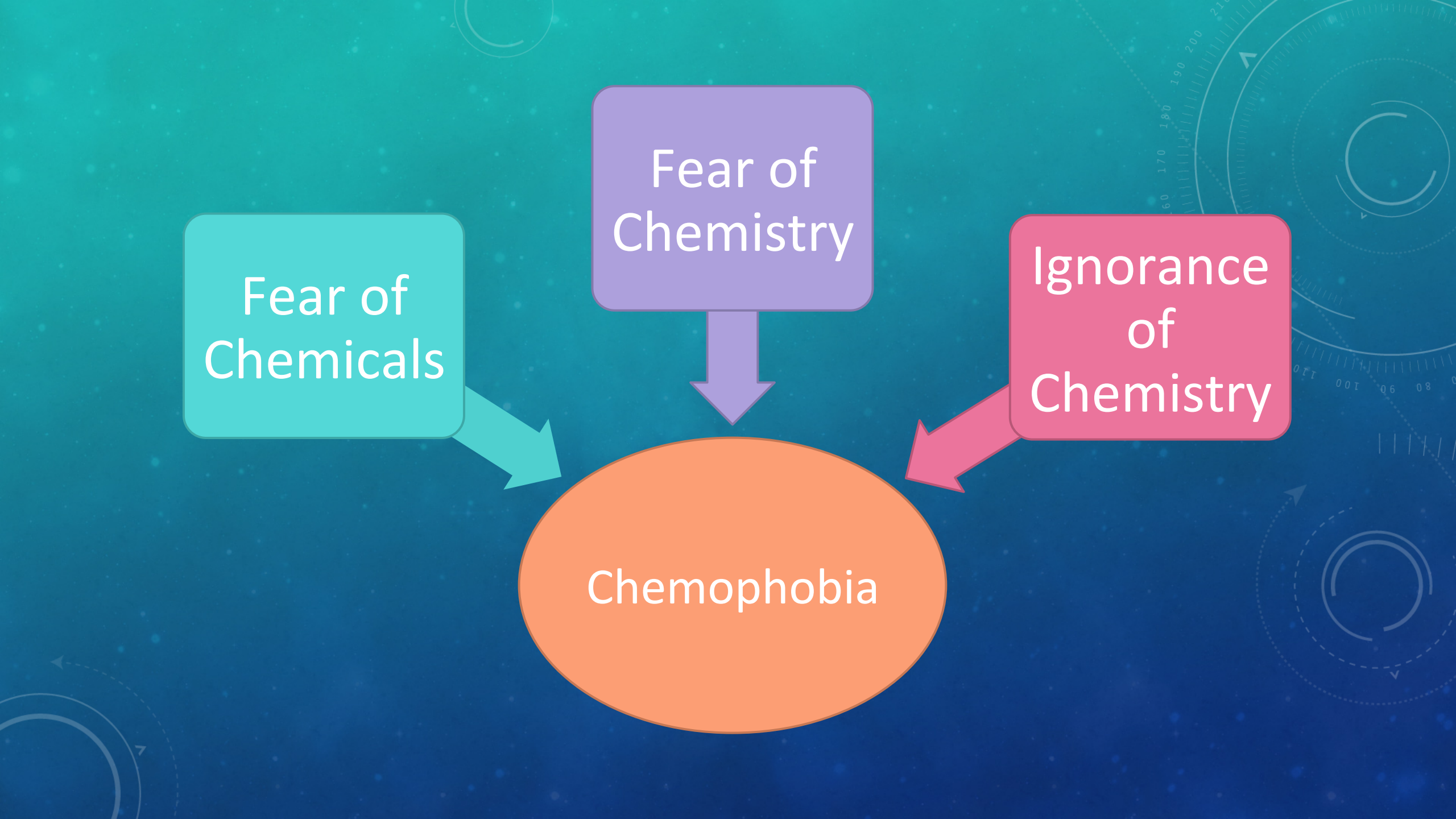


Fear of
Chemicals

Fear of
Chemistry

Ignorance
of
Chemistry

Chemophobia

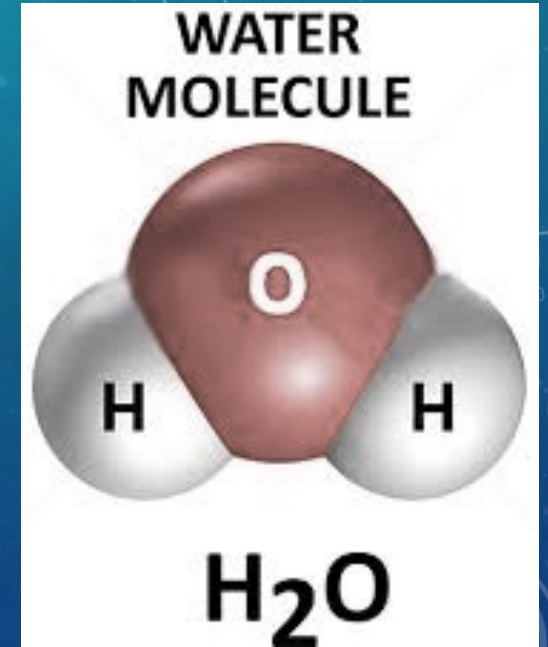
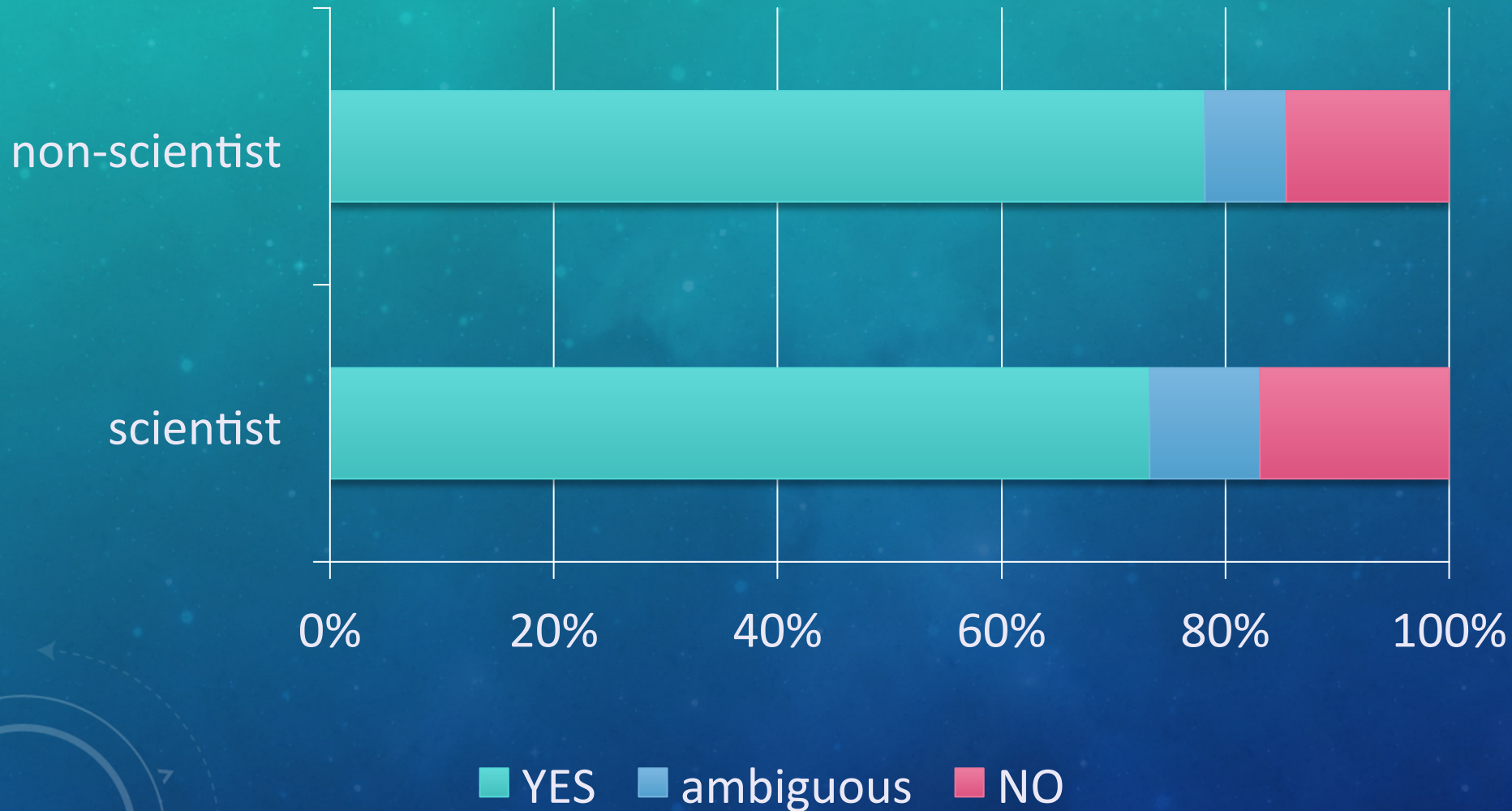




RSC #CHEMPERCEPTIONS

- Positive attitude towards chemistry (associated with school) and chemists (associated with pharmacists)
- Some ambiguity towards chemicals
- Most realised that 'everything is a chemical'
- Many define chemical as human-made/synthetic, toxic/harmful
- Many believe that natural chemicals are 'safer' than synthetic chemicals

STUDY 1: IS WATER A CHEMICAL?



STUDY 2: IS WATER A CHEMICAL?

% of 1 st year...	yes	no	don't know
chemistry	80.8	16.4	2.7
geography	74.4	22.1	3.5

“I would consider a chemical to be something 'man-made' rather than naturally occurring”

1st year Chemistry DH student

“you can drink water, you can't drink chemicals”

1st year Chemistry SH

WATER – WHAT'S IN A NAME?

- Oxidane [IUPAC recommended name]
- Dihydrogen monoxide [pedantic name]
- Water [common name, refers to liquid or vapour]
- Aqua [ingredient name]
- H₂O [chemical formula]

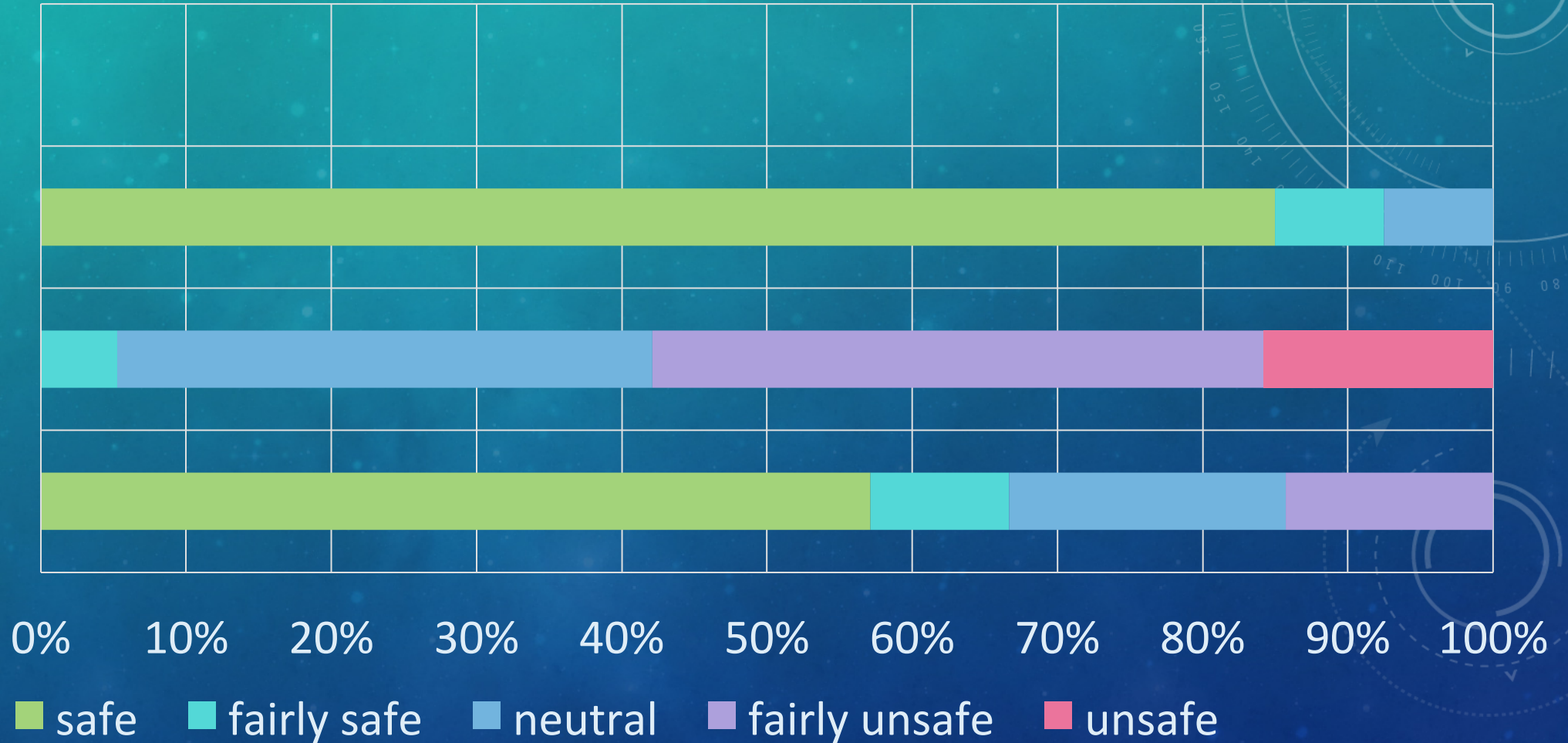
STUDY 1: WATER & RELATED

Water unknown

Water known

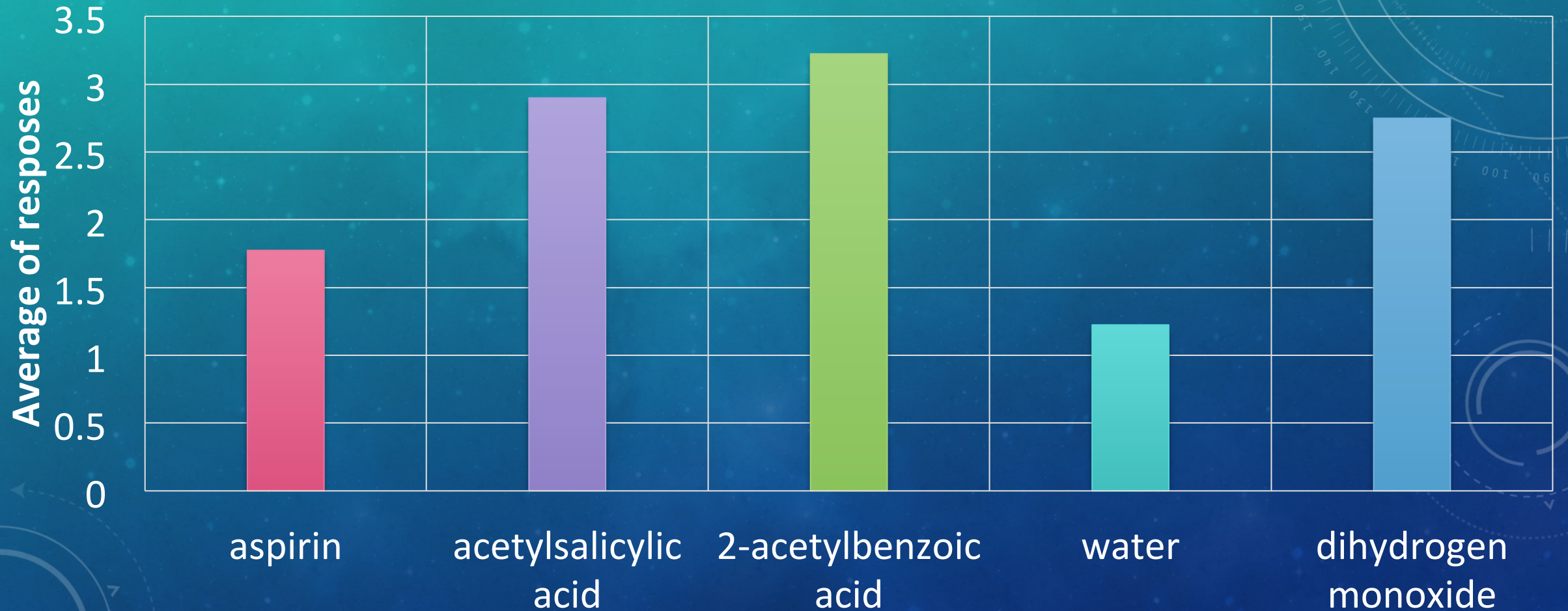
DHMO unknown

DHMO known



STUDY 1: TERMINOLOGY

Rate these substances 1 = Safe, 3 = neutral, 5 = Unsafe



BEYOND

- more data to analyse! [chemophobia]
- look at the links between what employers want and what we can provide

THANK YOU FOR LISTENING

The background is a blue gradient with faint technical diagrams and circular patterns. On the right side, there are several circular diagrams with tick marks and arrows, resembling a gauge or a scale. The text "THANK YOU FOR LISTENING" is centered in the lower half of the image.