Learning Astronomy Through An Immersive Science Fiction Experience

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ICHEP 2024

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A New Kind of University Class

An introductory astronomy class that blends a science fiction world and story with learning astronomy

- Designed for intermediate university students who are comfortable with low-level math and science

- Aims to increase engagement through an immersive narrative

- Develops "soft" skills like problem solving, critical thinking, creativity, and collaboration

- Increases intrinsic motivation to learn

- Fosters a "Learner Mindset" over "Performer Mindset"

- Gives students agency in what and how they learn

Course Symbol
The World Tree
Yggdrasil

Course Website
Spring 2024 Version

Why A Sci-Fi World?

- Creates a safe environment that mirrors our own society and allows students connect what they learn to the wider world
  - Makes the class highly interdisciplinary
- Offers an endless supply of interesting questions, estimations, and problems
  - Students can develop their problems
- Immerses students in the course material
- Adds purpose and meaning to the work done in the class
- It's fun!

Course Website
Spring 2024 Version
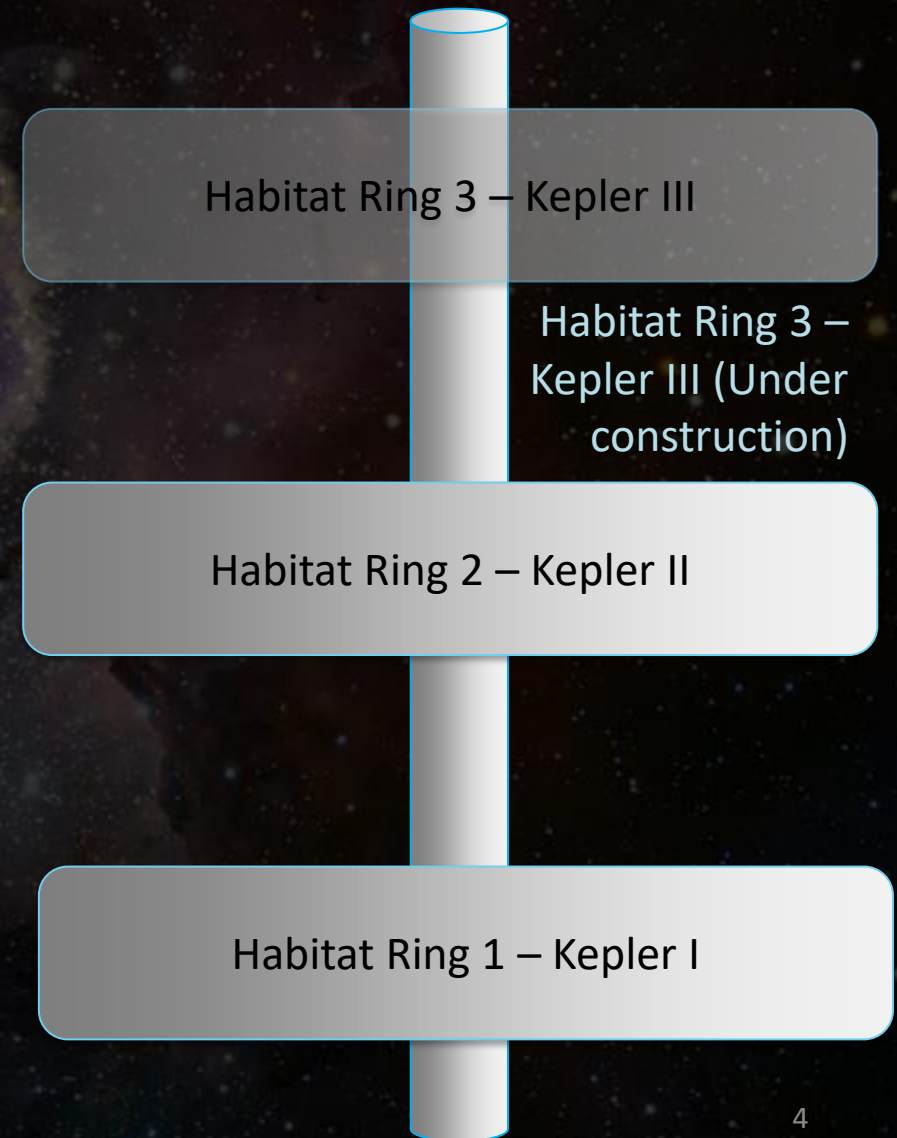
The Salvation of the Yggdrasil

The *Yggdrasil* is an intergenerational spaceship on they way to bring humans to their first new home amongst the stars

With nearly 180,000 people aboard, the Yggdrasil is a society in space with its own values, culture, and customs
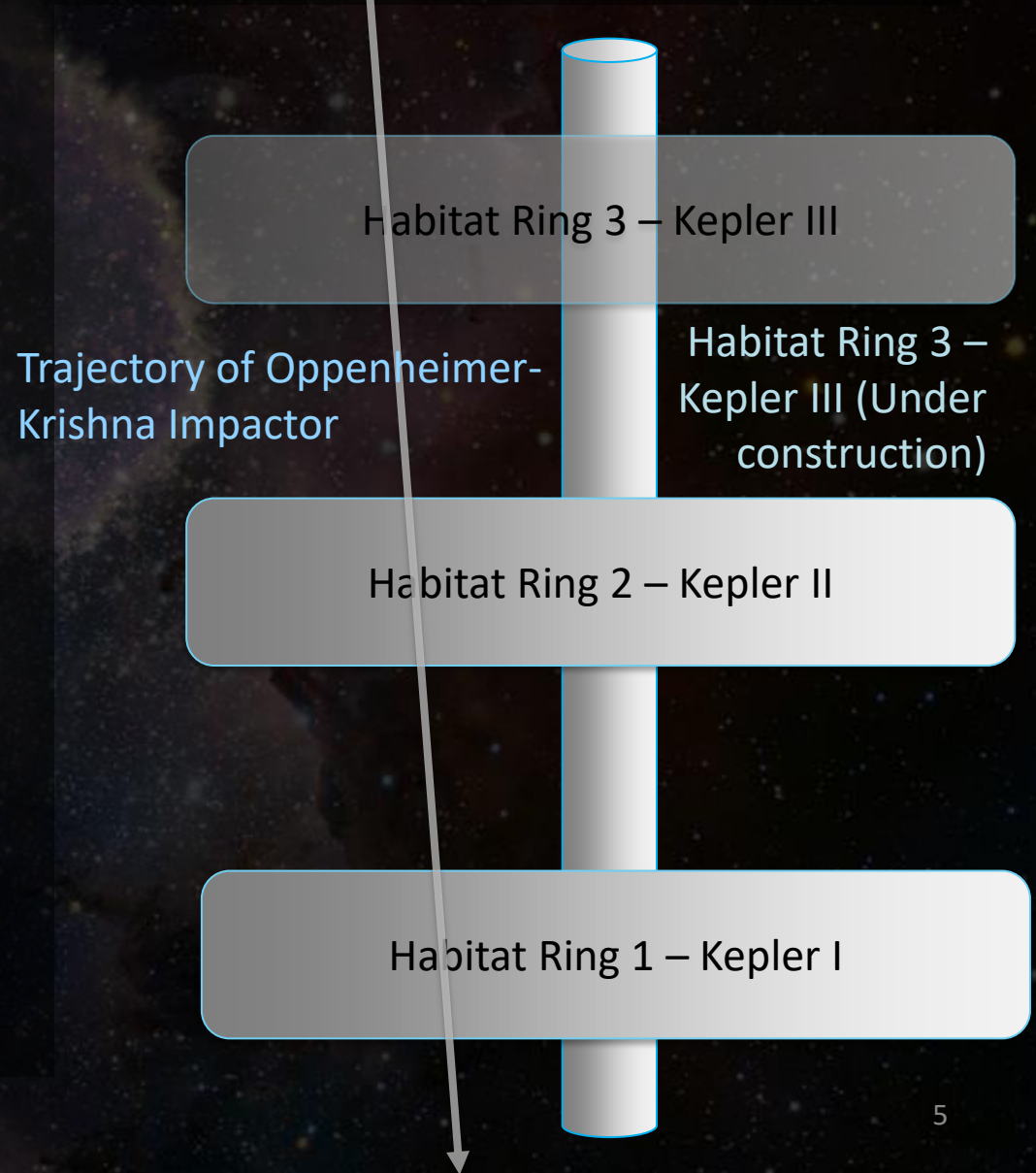
In the 178th year of the journey, disaster comes to the Yggdrasil when a molecular hydrogen iceberg strikes it piercing all three of its habitat rings

Habitat Ring 3 – Kepler III

Habitat Ring 3 – Kepler III (Under construction)

Habitat Ring 2 – Kepler II

Habitat Ring 1 – Kepler I

Chapter 1 – The Oppenheimer-Krishna Catastrophe

The impact event, known as the *Oppenheimer-Krishna Catastrophe (OKC)*, destroys much of the ship's infrastructure and kills nearly 20,000 people.

Much worse, most of hydrogen reserves used to power the hydrogen fusion generators & engines is lost.

After the disaster, only 30-years worth of hydrogen fuel remains

Trajectory of Oppenheimer-Krishna Impactor

Habitat Ring 3 – Kepler III

Habitat Ring 3 – Kepler III (Under construction)

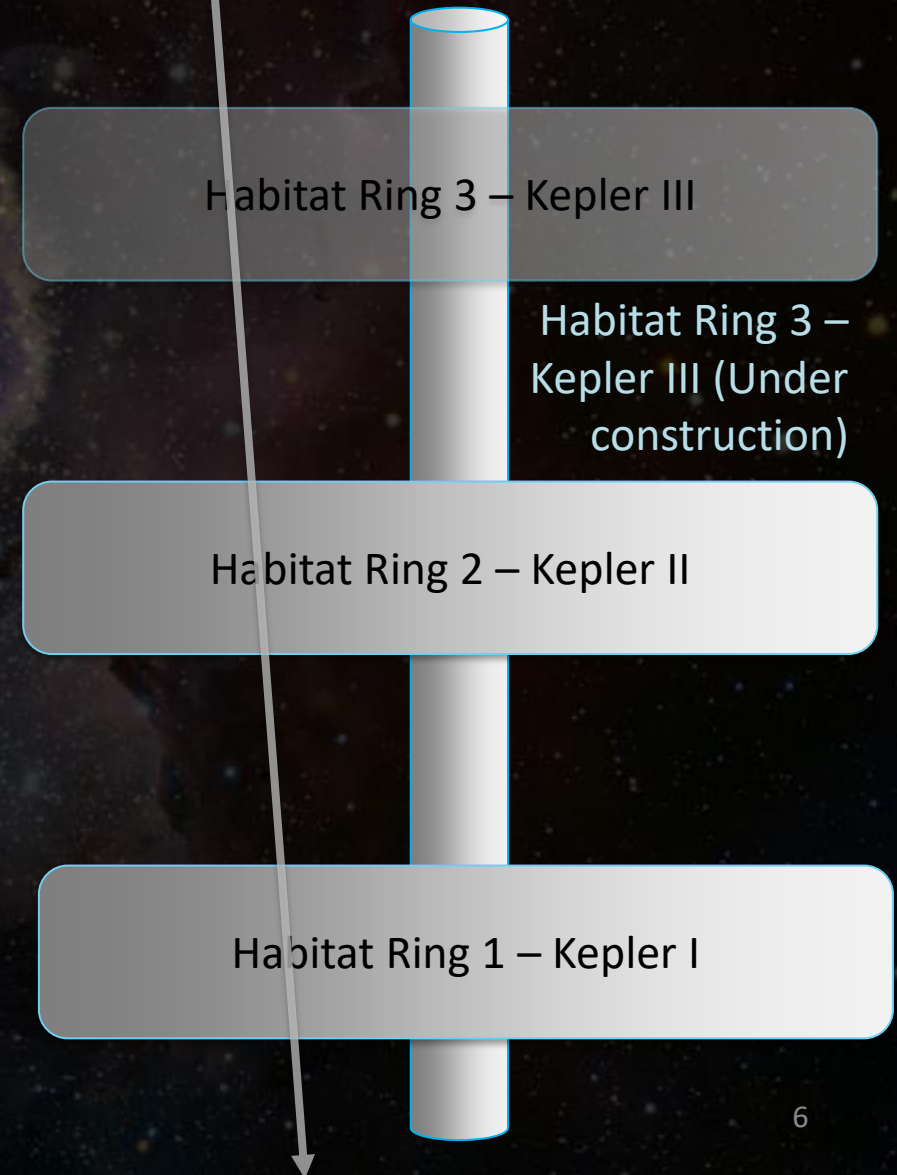Habitat Ring 2 – Kepler II

Habitat Ring 1 – Kepler I

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Chapter 1 – The OKC

To save the Yggdrasil, a fleet of ships must travel to a nearby main-sequence star, collect 125-years of hydrogen, and return to the Yggdrasil before the 30-year time limit expires.

Failure to do so means that the ship goes cold and dark, where eventually everyone perishes in space and this unique society is lost forever.

Can you and your team save the people of the Yggdrasil?

Habitat Ring 3 – Kepler III

Habitat Ring 3 – Kepler III (Under construction)

Habitat Ring 2 – Kepler II

Habitat Ring 1 – Kepler I

Chapter 1 Completion

Given

- The most recent *stellar parallax measurements*, *visible (V) and blue (B) magnitudes* of 20 stars

- The *acceleration* and *maximum relative velocity* for a small fleet of ships sent to gather the hydrogen and other resources

Students must identify a main-sequence star between the spectral types F7 and K3 and be able to get there and back to the Yggdrasil within the 30-year time limit.

The Daedalus Convoy

The Ygg

The Salvation of the Yggdrasil Scenario

- Students must apply the astronomy concepts learned in class to complete three chapters
  - Chapter 1: The Oppenheimer-Krishna Catastrophe
  - Chapter 2: Project Icarus
  - Chapter 3: The Enveloping Cosmic Dark
- Storyline and challenges written by Sean Lindsay Accompanying short stories written by Adam C. Tilley
  - Scenario, short stories, and accompanying documents is currently 64 pages long
- Upon completion, students must write an in-world chapter report demonstrating they understand the solution
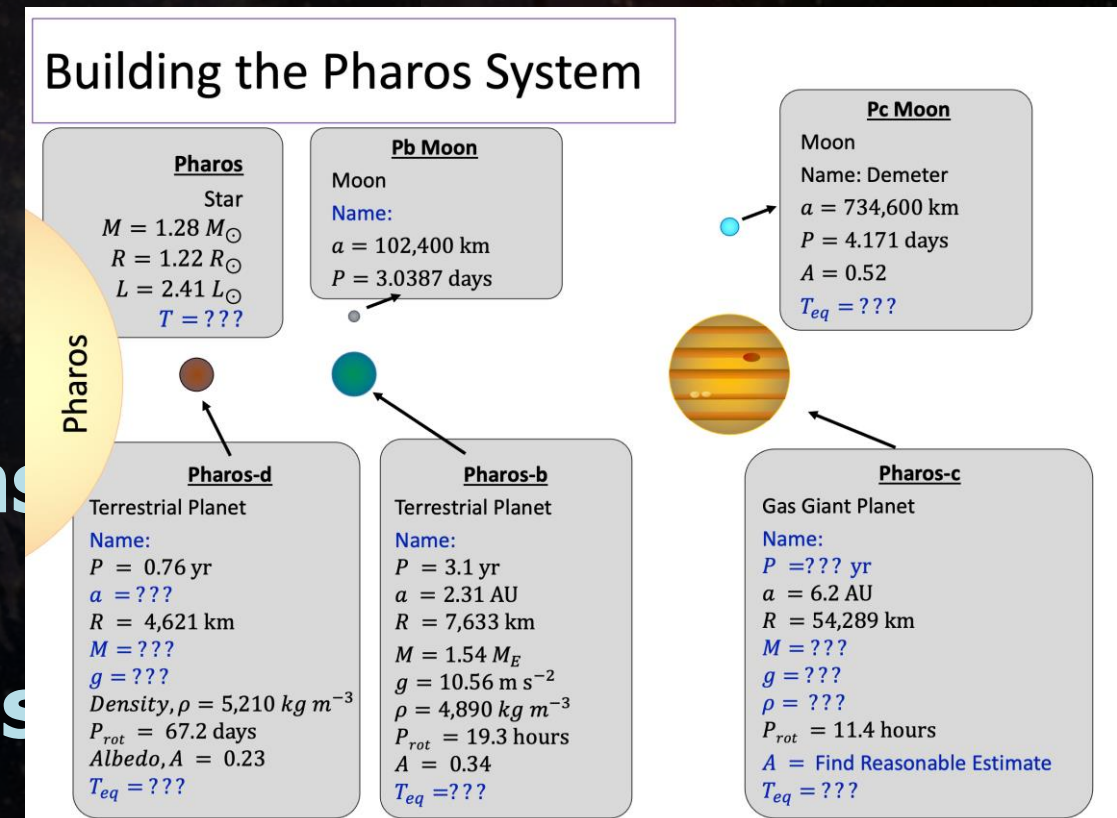
Other Parts of the Course

- **Selected Addition Projects**
  - "So, You Want To Build A Moon Base?" Project
  - Building the Pharos System
  - Add to the Ygg-World Project
  - Science, Technology, Society, and Ethics Project
- **Themed Challenge Problems**
- **Weekly Reflections**
- **Three One-on-One Meetings**

Building the Pharos System

Building the Pharos System

Pharos
Star
$M = 1.28\ M_\odot$
$R = 1.22\ R_\odot$
$L = 2.41\ L_\odot$
$T = ???$

Pb Moon
Moon
Name:
$a = 102,400$ km
$P = 3.0387$ days

Pc Moon
Moon
Name: Demeter
$a = 734,600$ km
$P = 4.171$ days
$A = 0.52$
$T_{eq} = ???$

Pharos-d
Terrestrial Planet
Name:
$P = 0.76$ yr
$a = ???$
$R = 4,621$ km
$M = ???$
$g = ???$
$Density, \rho = 5,210\ kg\ m^{-3}$
$P_{rot} = 67.2$ days
$Albedo, A = 0.23$
$T_{eq} = ???$

Pharos-b
Terrestrial Planet
Name:
$P = 3.1$ yr
$a = 2.31$ AU
$R = 7,633$ km
$M = 1.54\ M_E$
$g = 10.56$ m s^{-2}
$\rho = 4,890\ kg\ m^{-3}$
$P_{rot} = 19.3$ hours
$A = 0.34$
$T_{eq} = ???$

Pharos-c
Gas Giant Planet
Name:
$P = ???$ yr
$a = 6.2$ AU
$R = 54,289$ km
$M = ???$
$g = ???$
$\rho = ???$
$P_{rot} = 11.4$ hours
$A = $ Find Reasonable Estimate
$T_{eq} = ???$

Science, Technology, Society, and Ethics

- Students imagine what technology might exist in the futuristic sci-fi Ygg-world

- We go through a design thinking process to identify and develop a single technology to consider

- Identify the important ethical questions regarding this technology

- Decide if the technology should be regulated or banned

The Spring 2024 class chose to explore the ethics of brain-computer interfaces. The runner-up was nanobots

Develop Skills As Well As Knowledge

Student Character Sheets with Skill Points

- **Problem Solving**
- Research
- Critical Thinking
- Collaboration
- Creativity
- Connection
- Habits & Life

Thomas Pond

	Points	Progress	Level
Research	114.5		5
Problem Solving	244		10
Critical Thinking	123.5		5
Collaboration	70		3
Creativity	95		4
Connection	50		3
Habits & Life	30		2
Total Development	727		30

Jennin Kai'Jennin

	Points	Progress	Level
Research	80		4
Problem Solving	208		9
Critical Thinking	84.5		4
Collaboration	0		1
Creativity	40		2
Connection	60		3
Habits & Life	0		1
Total Development	472.5		19

Leader Boards

Research		
1st	Flourite Bluff	133
2nd	Thomas Pond	114.5
3rd	Jennin Kai'Jennin	80

Problem Solving		
1st	Thomas Pond	244
2nd	Jennin Kai'Jennin	208
3rd	Dirty Dan	204

Critical Thinking		
1st	Thomas Pond	123.5
2nd	Jennin Kai'Jennin	84.5
3rd	Shawn Spencer	76

Creativity		
1st	Flourite Bluff	115.5
2nd	Thomas Pond	95
3rd	Eleanor Lamb	77.5

Connection		
1st	Eleanor Lamb	65
2nd	Jennin Kai'Jennin	60
3rd	Shawn Spencer	50

Habits & Life		
1st	Eleanor Lamb	50
2nd	Benf Ranklin	45
3rd	Shawn Spencer	35

Collaboration		
1st	Thomas Pond	70
2nd	Benf Ranklin	56.67
3rd	Flourite Bluff	55

Overall Development		
1st	Thomas Pond	727
2nd	Jennin Kai'Jennin	472.5
3rd	Dirty Dan	457.5

Did It Work?

Selected Course Evaluation Responses

- "He encourages us to really critically think and *push ourselves to do the work, rather than just spectating, which is really where real learning comes into play.*

- "… opportunities to grow in areas such as emotional intelligence and reflection, critical thinking, and design thinking and goal setting. *These soft skills are essential to having a healthy relationship with learning and especially with education.*"

- "Using the scenario in order to go through the material made it much easier to get invested in actually learning the topics, and *made it feel like the topics we learned would have an actual impact.*"

Abridged Summary

- I've created a highly interdisciplinary introductory astronomy course that blends science fiction narrative with learning foundational astronomy concepts

- Framing class activities in a sci-fi world offers students the opportunity to engaged with interdisciplinary work, develop soft skills, and see the course concepts apply outside the typical classroom environment

- Reaction to the class and initial quantitative and qualitative data suggest the class increased intrinsic motivation and desire to engage with the material and concepts

Ask Me About

- Preliminary results of how well the class worked
- The next version of the class
- The other "Salvation of the Yggdrasil" Chapters
- Where a class like this fits into a department's curriculum
- Potential collaborations with other instructors and academic units to create spin-off classes or shared course units
- Alternative assessment strategies I used
- The class's skill point and leveling system
- Incorporating human-centered design into collaborative class sessions
- How to incorporate meaningful student collaboration
- Self-determination Theory applied to education
- Using Google Sites to have students create websites for their projects
- The topics covered in class

EXTRA SLIDES

Recommendation for Implementation

Adopting elements of "story-based learning" in your classes

- Develop questions & projects that give students
  - Choice to explore a topic more deeply along lines of a student's own interests
  - Have story narratives that highlight how the material connects to the "bigger picture"
  - Are fun and have multiple steps that engage deep problem-solving
- Build a relationship-rich classroom environment
- Try it yourself: Build a scenario (small or grand) related to your course material
- Create coursework that incorporates meaningful collaboration

Sample of Chapter 1 Resources

– Yggdrasil Operating Parameters –
Ship Parallax Definitions

Synopsis:
The Yggdrasil measures stellar parallax via 24 survey-class drones equipped with 25-cm Nuevel Optics Schmidt-Cassegrain reflecting telescopes and ADX-N128 CMOS detectors. The 24 survey-drones are split into two groups of 12 that travel 10^{10} km fore and aft of the Yggdrasil. For stellar parallax surveys, starfield images are taken at the terminal points of 10^9 km linear traverse. This gives a stellar parallax baseline distance of 10^9 km. Half of this baseline distance, $5*10^8$ km, is defined to be 1 parallax distance, 1 pd. With this baseline, a parallax of 1 arcsecond defines 1 cosmic distance (cd), which is the ship-standard

Ship Document Describing How the Yggdrasil Measures Parallax

Sample of the Stellar Targets Tables

Star Designation	Ship Parallax (arcsec)	Apparent visible magnitude V	Apparent blue magnitude B
ST-353-R04-024	0.102	3.714	3.765
ST-353-R42-391	0.204	1.477	2.687
ST-353-R12-229	0.051	1.762	1.540
ST-353-R35-517	2.958	-3.025	-2.911
ST-353-R25-945	3.223	0.659	1.419

Build a lunar habitat that can sustain a population of 100 for at least 10 years

Student Projects

- Energy generation
- Recreation Center
- Radiation Shielding
- Base Architecture
- Growing Food
- Waste Management

Story-Based Learning

Story-based Learning Pedagogy

- Scenario-based Learning   Problem-based Learning
  Project-based Learning   Human-centered Design

Educational Philosophy

- A learner mindset is created through fostering intrinsic motivation
- Students learn best in a relationship-rich environment
- Contextualize material through practice and interdisciplinary connections
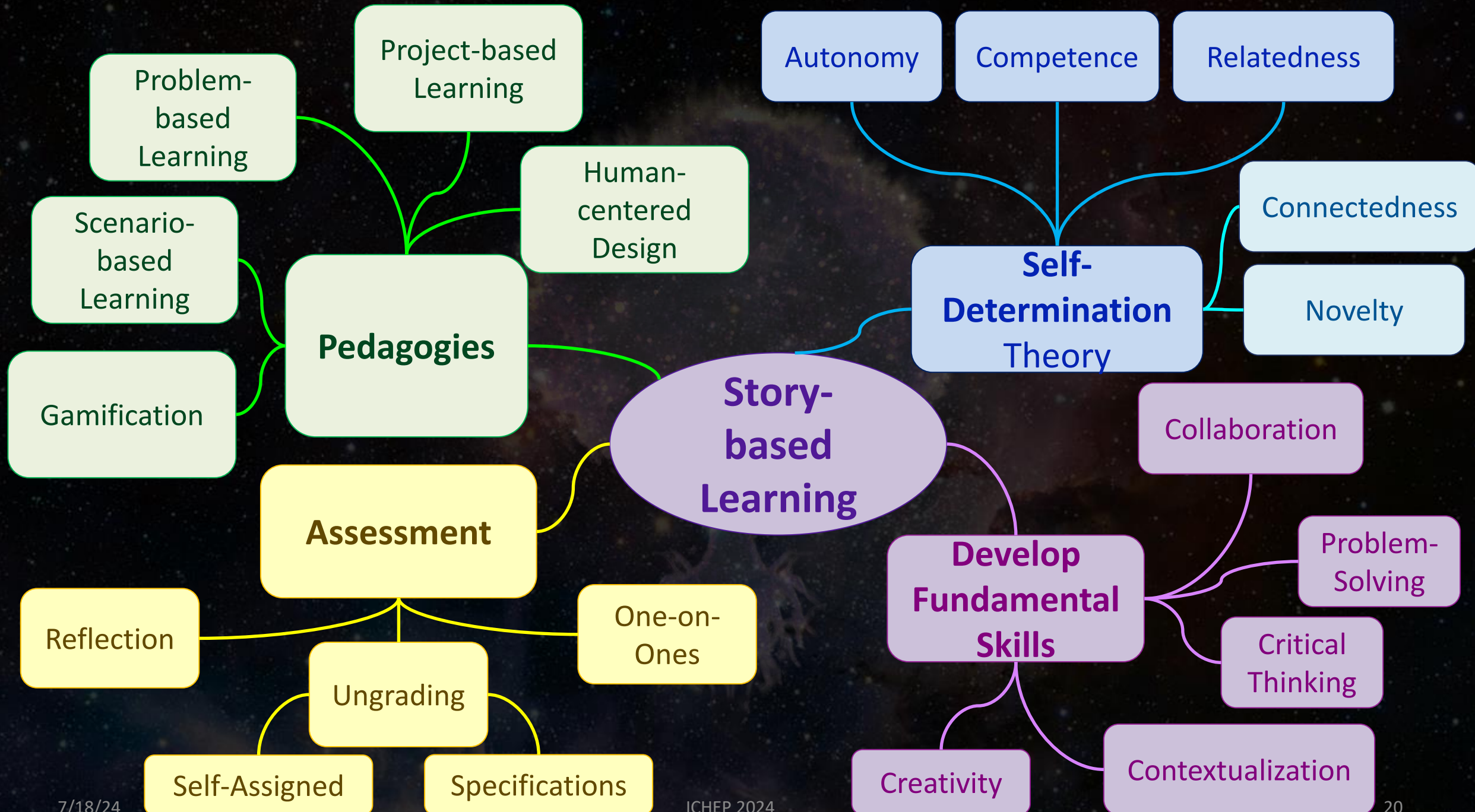- Success through learning from mistakes

Self-Determination Theory

   Autonomy   Competence   Relatedness
              Novelty   Connectedness

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The Future of the Class

Part 1

Welcome to the Yggdrasil World

Problem-Solving & Estimation

Part 2

Project 1a:
Yggdrasil Physical Structure

Project 1c:
Solving a Ygg-World Problem

Project 1b:
The Yggdrasil Society

Part 3

Project 2:
Science, Technology, Society, and Ethics (STSE)

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The Future of the Class

Part 4

Project 3a:
Characterizing the Destination Planet

Project 3b:
Ollie's World

Project 3c:
The Yggdrasil's Got Mail –
A Message to Aliens

Part 5
The Salvation of the Yggdrasil

Chapter 1:
The Oppenheimer-
Krishna Catastrophe

Chapter 2:
Project Icarus

Chapter 3:
The Enveloping
Cosmic Dark

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Class Collaboration Methods

Chapter Introduction & Group/Class Problem Solving Strategy Building

Individual or Small Group Work

Continues Until 50% of Class Reports That They Think They Have The Answer

Peer Teaching

Continues Until 75%

Class Unification Phase

Continues Until Class Agrees Upon Solution to Present
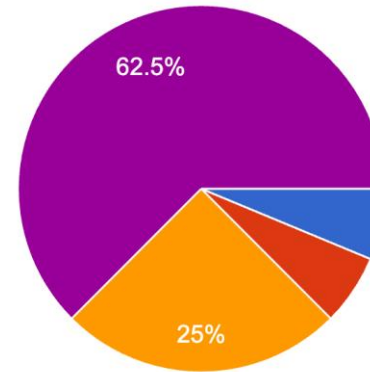
Class Presentation of Solution

Did It Work?

Pre-Semester
Thinking about classes within major

Intrinsic Motivation

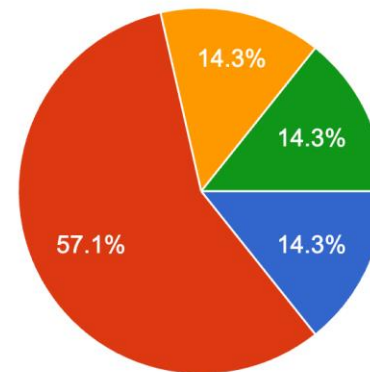Post-Semester
Thinking about this class

Most of the school work I do feels like "I have to."
16 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

62.5%
25%

2. Most of the school work I do feels like "I have to."
7 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True
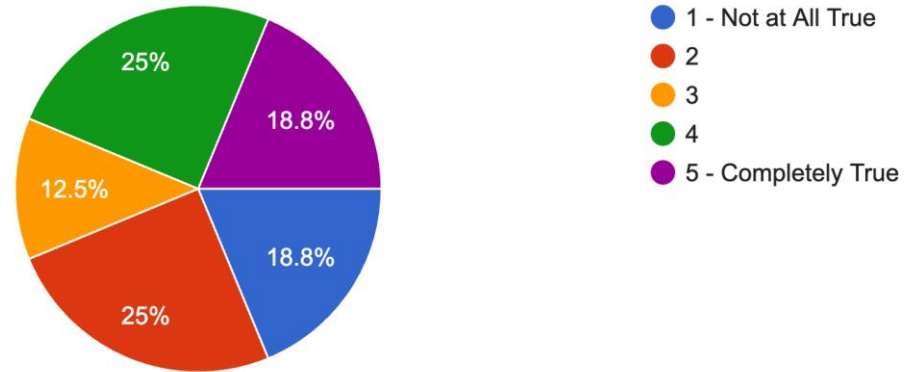
14.3%
14.3%
57.1%
14.3%

Did It Work?

Pre-Semester
Thinking about classes within major

Student Engagement

Post-Semester
Thinking about this class

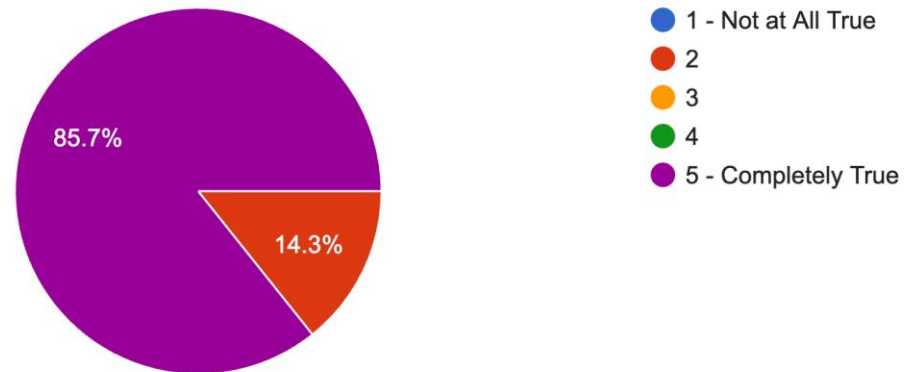In class, I feel the work is presented in a way that captures my attention.
16 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

25%
18.8%
12.5%
25%
18.8%

29. In class, I feel the work is presented in a way that captures my attention.
7 responses

- 1 - Not at All True
- 2
- 3
- 4
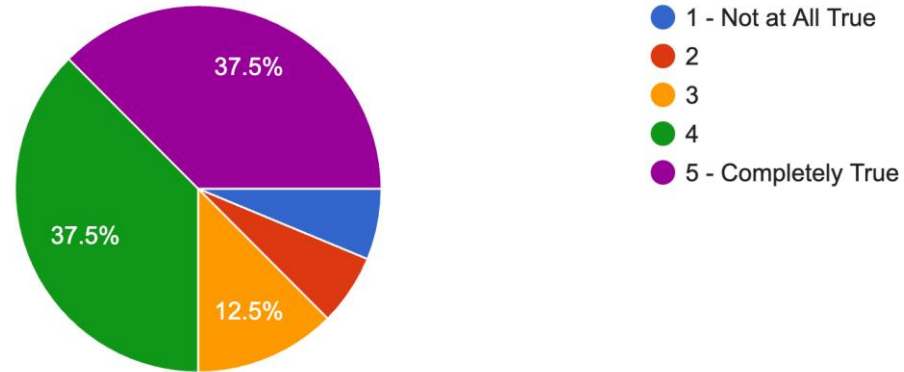- 5 - Completely True

85.7%
14.3%

Did It Work?

Pre-Semester
Thinking about classes within major

## Interdisciplinary Connections

Post-Semester
Thinking about this class

I feel like I can take what I have learned in this class and apply it to other disciplines.
16 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

37.5%
37.5%
12.5%

32. I feel like I can take what I have learned in this class and apply it to other disciplines.
7 responses

- 1 - Not at All True
- 2
- 3
- 4
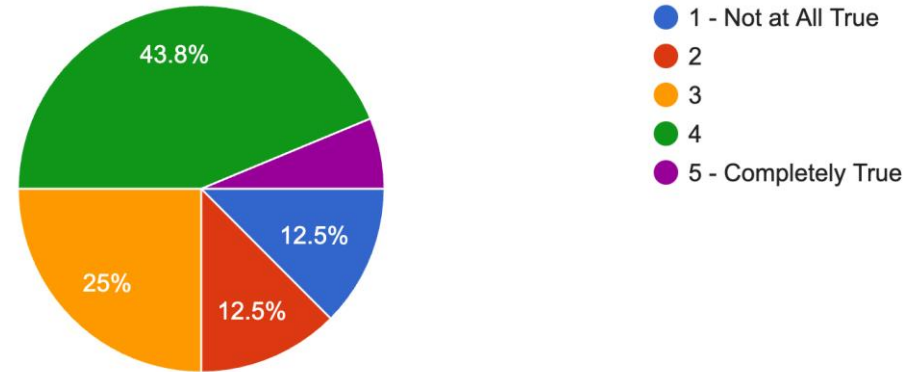- 5 - Completely True

85.7%
14.3%
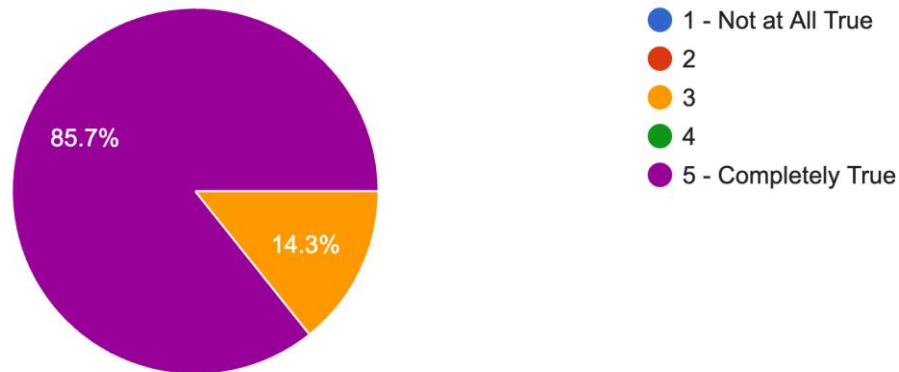
Did It Work?

Pre-Semester
Thinking about classes within major

Competence

Post-Semester
Thinking about this class

In class, I feel capable at completing the tasks set to me.
16 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

43.8%
12.5%
25%
12.5%

14. In class, I feel capable at completing the tasks set to me.
7 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

42.9%
14.3%
28.6%
14.3%
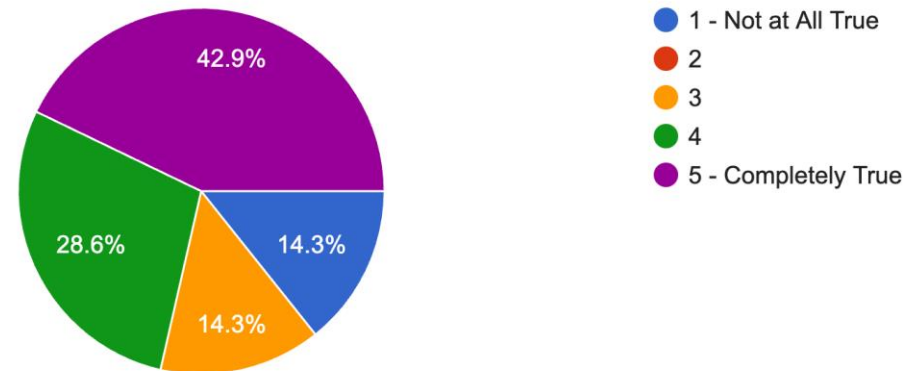
Did It Work?

Pre-Semester
Thinking about classes within major

Relatedness

Post-Semester
Thinking about this class

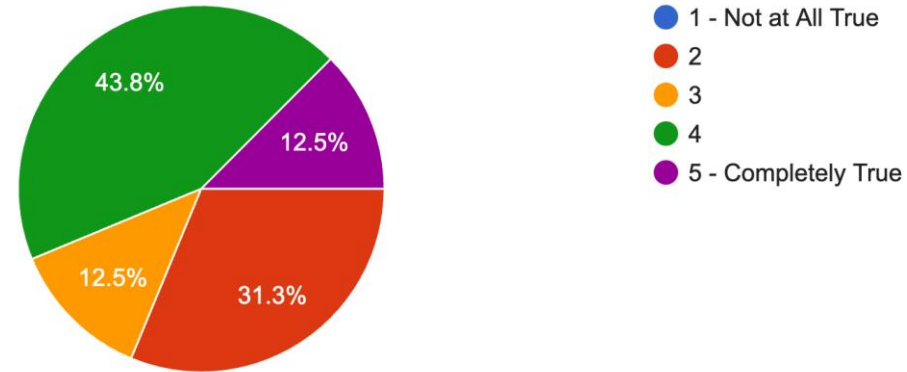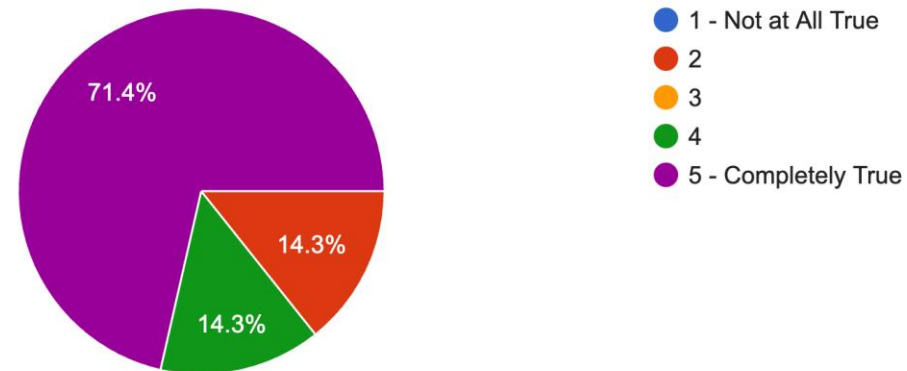I feel very comfortable with my teacher and classmates.
16 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

43.8% / 12.5% / 12.5% / 31.3%

4. I feel very comfortable with my teacher and classmates.
7 responses

- 1 - Not at All True
- 2
- 3
- 4
- 5 - Completely True

71.4% / 14.3% / 14.3%

Meaningful Collaboration

- Group work should be preceded by individual work
  - Have students do a brainstorming session about a topic or problem before the course work
- The majority of group work should take place *in class*
- Conduct empathy interviews at the beginning of the class
- Attempt to make groups with a diversity of learning perspectives, strengths, and weaknesses
- Create a "group liaison" who takes the ideas and thoughts from their group and shares them with another. Have them report back to their home group

Future of SotY Chapter Work

Day 1
Phase 1

Introduce story and problem of the chapter

In small groups, the class brainstorms solution strategies (no hard calculations allowed)

Solution strategies shared with the class

Phase 2
Individual/Small Group Work

Students work on solving the chapter

A student reports when they think they have a viable solution

Phase 2 ends when 50% of class reports having solution

Phase 3
Peer-Teaching

Students who think they have a solution help those who need it

Students can host mini-lesson to teach chapter-related concept

Phase 3 ends when 75% of class report having solution

Future of SotY Chapter Work

Phase 4
Class Unification

Class collaborates and agrees upon a solution to present for review.

Solution can be presented as a presentation or write-up

Entire class must agree to have solution presented

If a Correct Solution Presented

Move to the next chapter and start at Phase 1

If Incorrect Solution Presented

Everyone on the Yggdrasil perishes.

Students must do a reflective "obituary" identifying where they went wrong

Once completed, new numbers are generated and the class returns to Phase 4: Class Unification

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Sample of Chapter 1 Resources

10^{10} km

Distance

p

Measured parallax
$2p$