



Building a Visionary Astrophysics Program from the Ground Up

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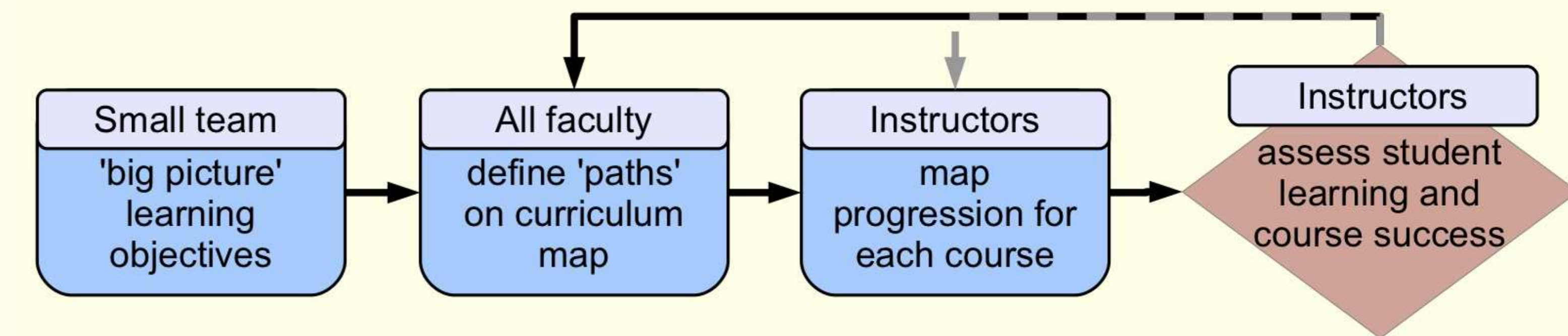
IfA Undergraduate Education

To ensure students in the University of Hawaii's new undergraduate astrophysics program develop a solid foundation in physical theory, its application to astrophysical phenomena, and observational astronomy skills, we are developing a curriculum map of the field of astrophysics to guide course design.

We draw upon key principles identified in education research: a reductionist examination of knowledge and skills working backwards from end-goals facilitates effective teaching (**backward design**^[1]), continuous assessment throughout one's teaching allows for needed adjustments (**formative assessment**^[2]), and a focus on the process of science boosts student motivation and learning (**engaged learning**^[3]).

^[1]Wiggins, G. P., McTighe, et al. (1998) *Understanding by design*. ^[2]Boston, C. (2002) *The Concept of Formative Assessment*. ^[3]American Association for the Advancement of Science (1989) *Science for all Americans*

Design process



Our design process includes several stages, and offers multiple levels of feedback as we implement our new major. Crucially, we will revisit both our sense of how to build student understanding and the effectiveness of our courses in teaching students.

Learning objectives

- Laws of Physics** classical mechanics, thermodynamics and statistical mechanics, electromagnetism, optics, relativity, and quantum mechanics
- Astronomical Objects** nature, structure, distribution, and formation
- Physical Laws in Astronomy** universality of physical laws and their application
- Astrophysical Problems** formulate astrophysical problems in mathematical terms; solve with analytic and numerical methods
- Scientific Method** ask meaningful questions, design experiments, acquire and critically analyze data, draw appropriate conclusions
- Scientific Communications** communicate research design and results
- Observational Properties** define and interpret observational properties
- Astronomical Data Reduction** reduce astronomical images and spectra using standard analysis software; measure properties
- Observing Methods** propose, plan, and conduct astronomical observations with professional telescopes
- Astronomical Literature** use astronomical literature, databases, and on-line catalogs to obtain relevant information

Curriculum map excerpts

Items in **red** from the following subsample of our curriculum map are addressed in the sample learning tasks listed under Implementation (right).

Subject	Introduction	Basic usage	Mastery
1. Laws of Physics (excerpt)			
Classical mechanics (forces)	use of free-body diagrams; use of Newton's laws	forces in 2D & 3D; pressure as force / area	time and position varying forces; the use of differential equations
Classical gravity	identify gravitational influences & calculate static effect	circular orbits ; tides	elliptical orbits , continuous mass distributions
2. Astronomical Objects (excerpt)			
Stars	Properties and their relations: mass, luminosity , temperature, lifetimes, radii ...	Processes: fusion → luminosity; post-main sequence evolution ...	IMF and observed populations as sum of multiple generations ..
4. Astrophysical problems (excerpt)			
Represent physical situation in mathematical terms	verbal and schematic descriptions	match descriptions to known functions	construct formulae, derivatives, & integrals
Algebra	Map physical situation to known functions ...	Symbolic manipulation ...	Combine functions to explore relations between variables ...
9. Observing methods (excerpt)			
Telescope capabilities	resolution (spatial, temporal , spectral/energy), sensitivity , range	Statistics & noise characteristics, foregrounds & background saturation and detectability	Confusion; detector limited, sky limited, and more detailed S/N calculations

Implementation

The following sequence of student tasks illustrates how the curriculum map excerpts to the left were used to ensure introductory concepts build sequentially, through a subset of our courses, to mastery of core astrophysics concepts.

1st year Physics

Use $f_{\text{gravity}} = \frac{GM_1 m_2}{r^2}$ to calculate gravitational force and how it varies with mass and distance
 Use $a_{\text{centripetal}} = \frac{v^2}{r}$ to determine an object's acceleration and net force acting upon it

2nd year Astrophysics

Combine gravity and circular motion to relate orbital period to stellar mass for circular orbits and a high mass ratio.

3rd year Observational Astronomy

Determine orbital period of a binary system from a sequence of images.
 Model how varying inclination and orbital parameters alters light curve of binary
 Plan observations to measure orbital period of a binary system given position and luminosity.

3rd year Mechanics

Calculate solutions to two-body orbits

4th year Stellar Astrophysics

Given a light-curve, estimate the masses of two stars in a binary system (with uncertainties).