Visual storytelling of scientific data: collaborations between art and physics in the college classroom

Collaboration for Student Success:

2019 Advising, Applied Learning and Student Success Summit

October 28, 2019

Dr. Eric Edlund and Dr. Szilvia Kadas
SUNY Cortland

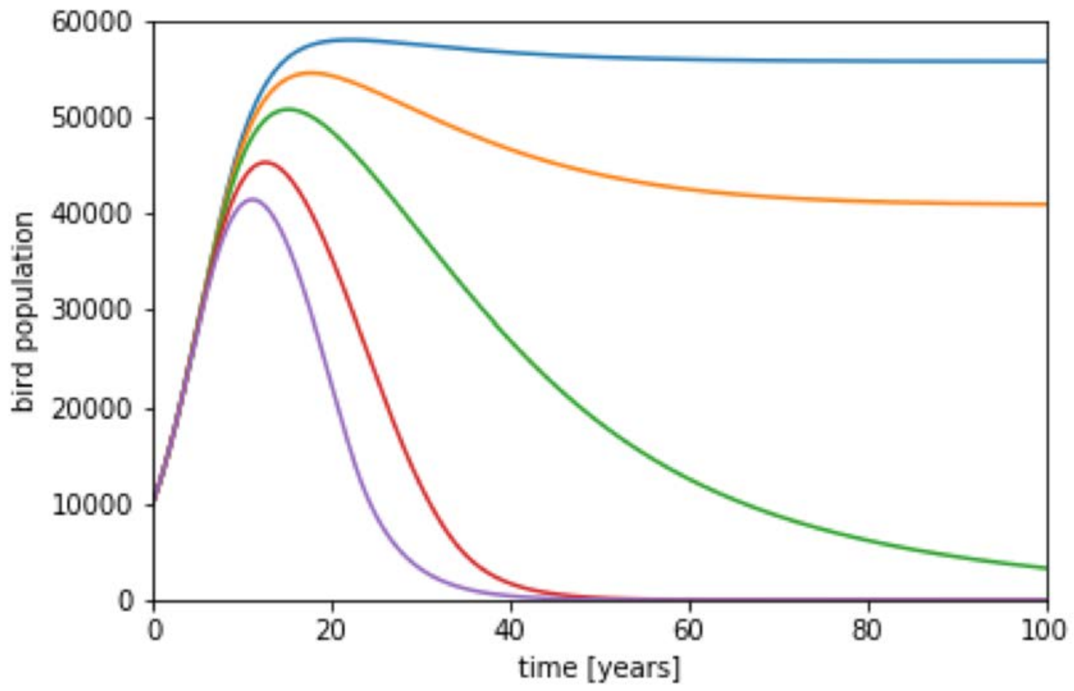
Common Problem Pedagogy (CPP)

The goal is to have teams develop cross disciplinary perspectives, that adds important dimensions to their effort.

Focus:

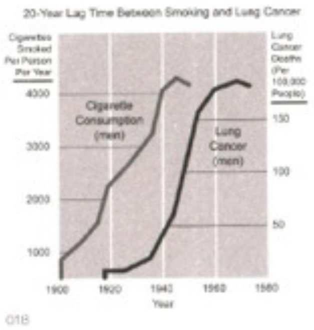
- Interdisciplinary teamwork
- Problem-solving
- Applied/experiential learning
- Socially conscience
- Funded by an NSF Grant
- SUNY Oneonta, SUNY Oswego, SUNY Cortland, SUNY Plattsburgh

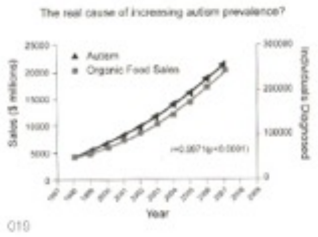
Connection between art and science

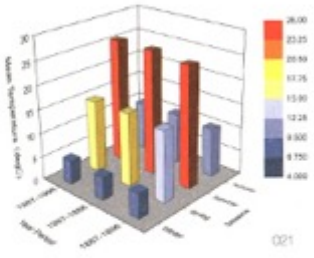


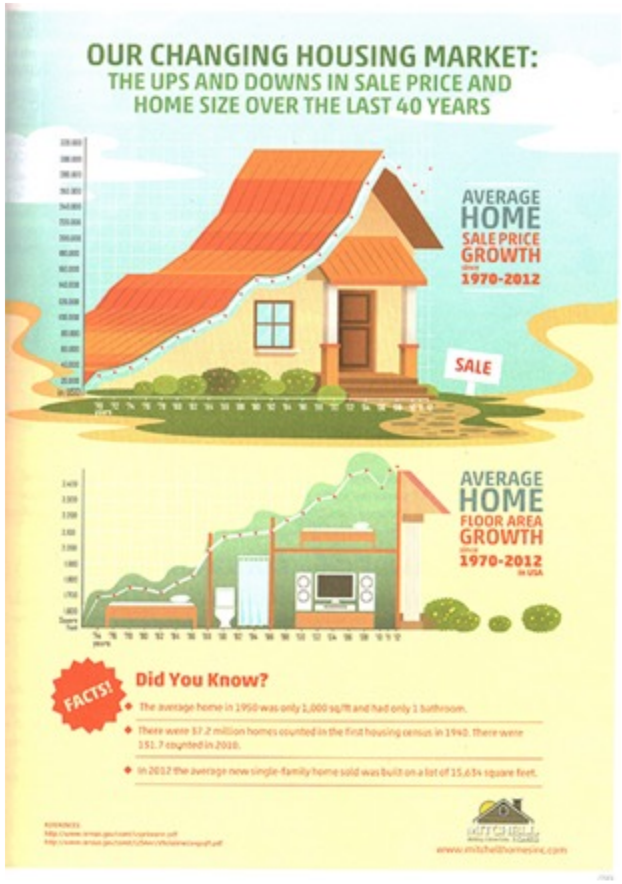
Student Project: Impact of organo-chlorides on birds of prey

Infographics









Yikum, K. & Zhao (2013) Visual Storytelling p. 27

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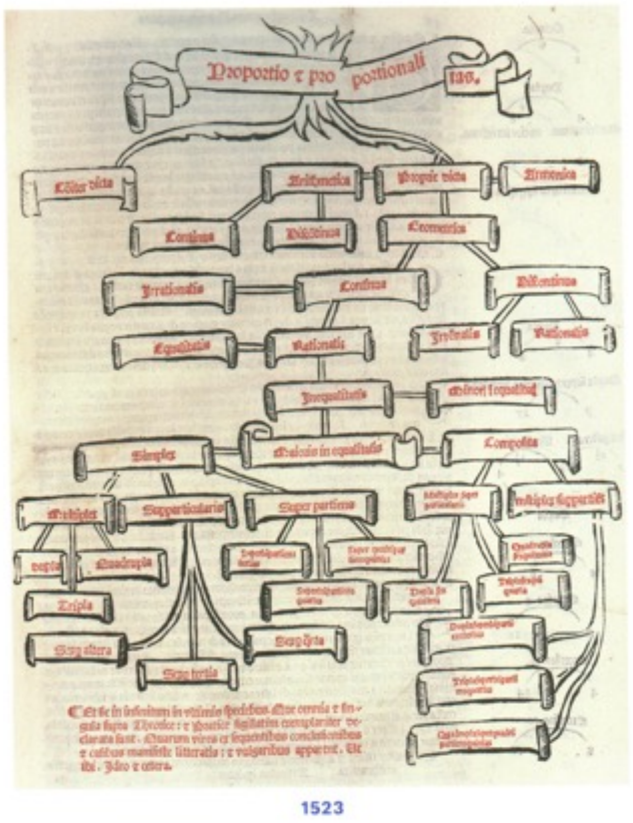
Infographics – history



Summa de Arithmetica, Franciscan friar Luca Pacioli

Georg Bartisch, Ophthalmology Book, Rendgen, S. (2012) Information Graphics, (pp. 26-27), Taschen

Planning and organization

Our constraint:

- Asynchronous communication

Our solution:

- Division of work process
- Primary communication through Blackboard
- Exchange of data in technical reports

Students collaborating in the sole person-to-person meeting.

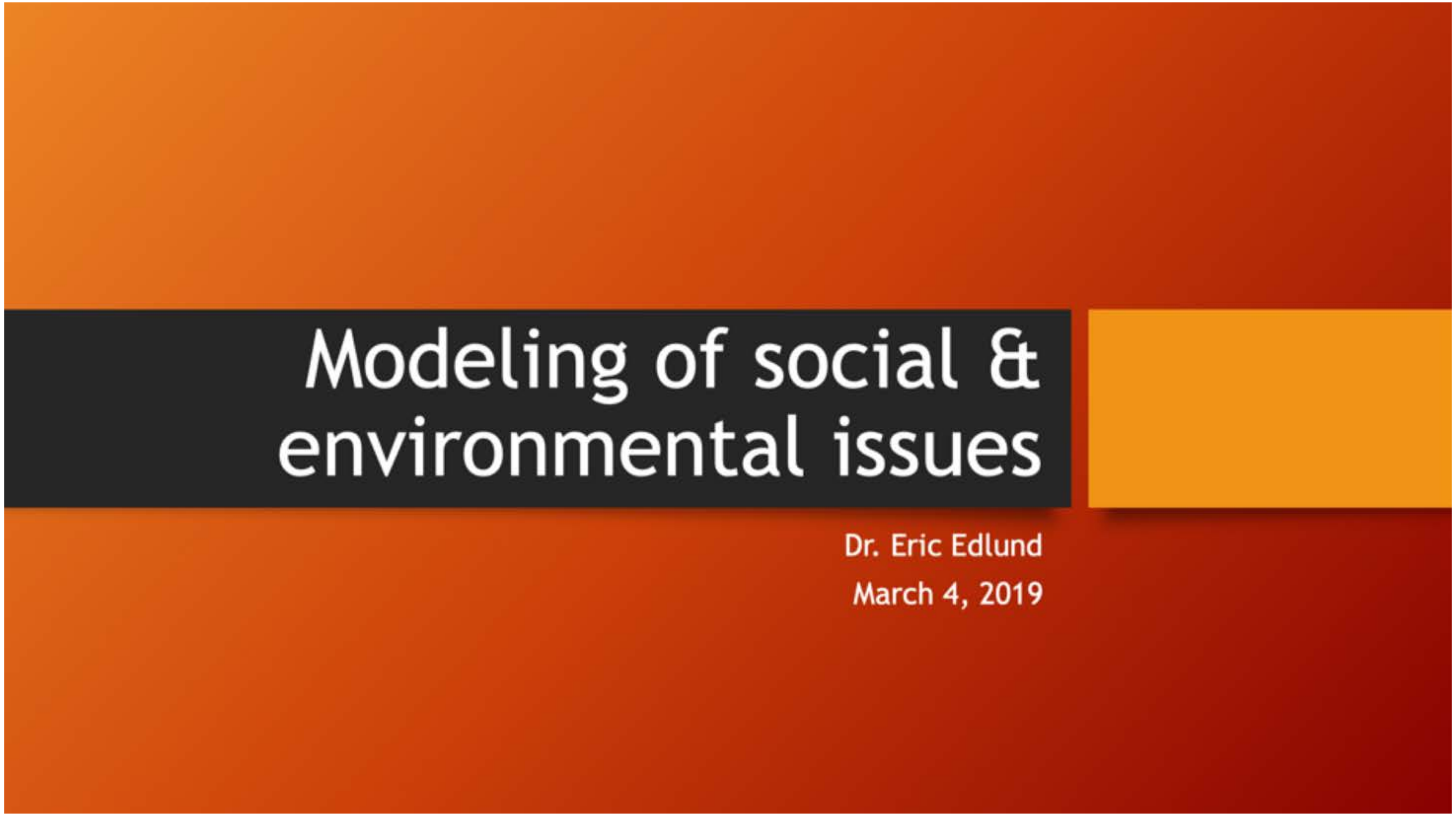
Timeline

- March 1 – Design students list areas of social/environmental concern
- March 15 – Preference for topical areas due
- March 25 – Identification of four articles
- March 29 – Definition of four specific questions
- April 3 – Selection of specific question
- April 5 – Development of the numerical model
- April 15 – Report on numerical model
- April 21 –Data available to Design Students
- April 22- Begin working with data: Lecture, Group Activity
- May 8- Final Project Due: Common Problem Project Presentations
- May 9-17 - Project Exhibition: Dowd Hallway Gallery

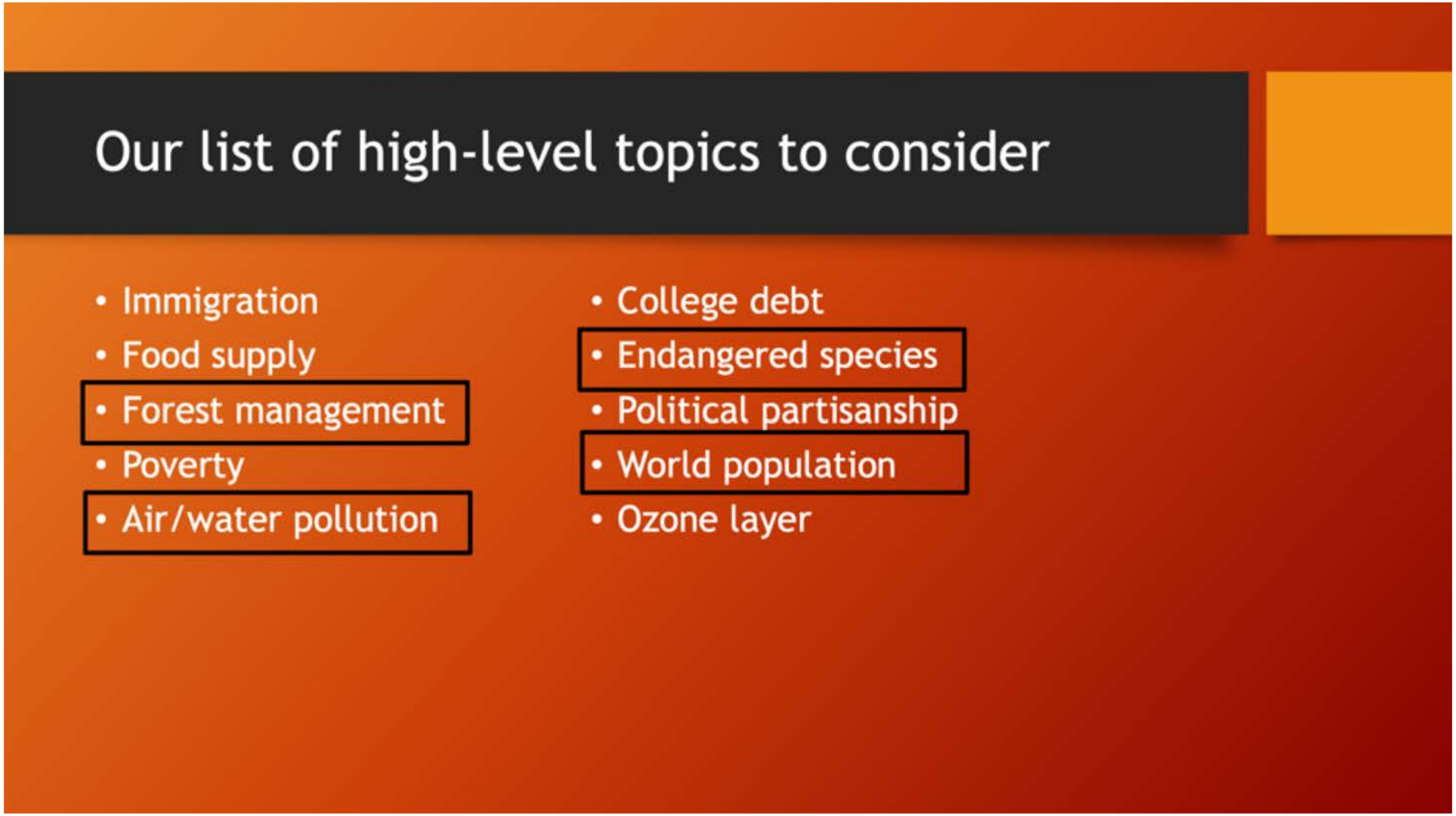
Physics students

Design students

Concept development



Concept development



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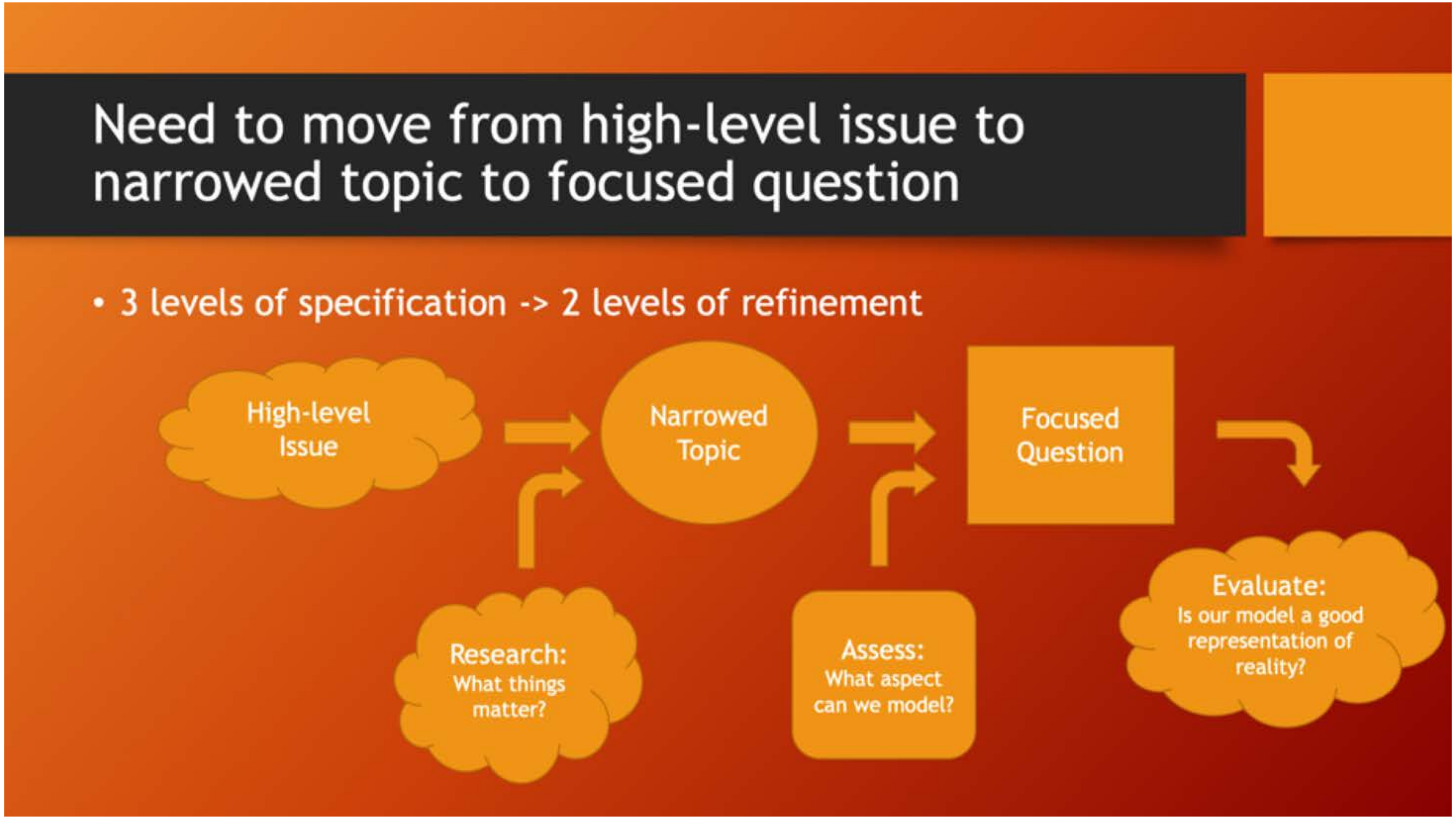

Concept development

In recent news

https://www.nytimes.com/2019/02/28/climate/fish-climate-change.html

The World Is Losing Fish to Eat as Oceans Warm, Study Finds

"Fish make up 17 percent of the global population's intake of protein, and as much as 70 percent for people living in some coastal and island countries, according to the Food and Agriculture Organization of the United Nations."

"Warm areas fared even worse when they were overfished. The researchers suggested that overfishing made fish even more vulnerable to temperature changes by hurting their ability to reproduce and damaging the ecosystem."

Concept development

Example: brainstorming for sustainability

Phase 2: Generate a specific question for each well-defined issue.

- How do variations in wind affect the price of electricity?
- How does a carbon tax that depends on the average annual global temperature affect economic growth?
- How does the use of a limited food resource affect population growth?
- How does the implementation of police suppression of riots affect the long-term tendency of a population to revolt?
- How does the number of vacation houses affect one's happiness?

Creating a model

The story of the fish and the fisher-people:

$$\frac{d}{dt}P_{fish} = \frac{1}{\tau_{fish}}\left(1 - \frac{P_{fish}}{P_{fish}^{max}}\right)P_{fish} - RP_{humans}$$

$$\frac{d}{dt}P_{humans} = \frac{1}{\tau_{humans}}\left(1 - \alpha\frac{P_{humans}}{P_{fish}}\right)P_{humans}$$

Creating a model

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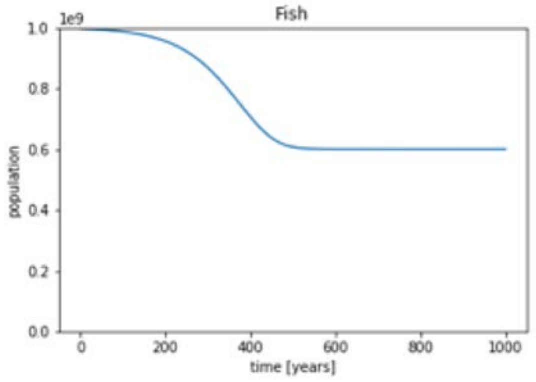

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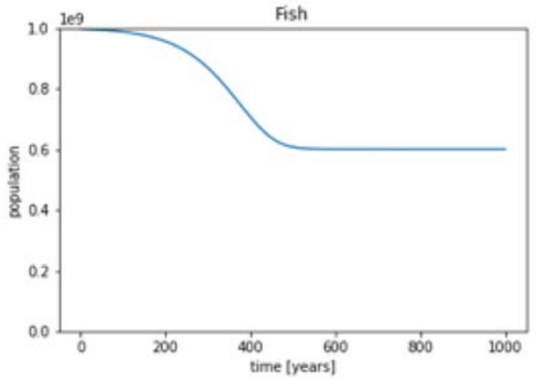
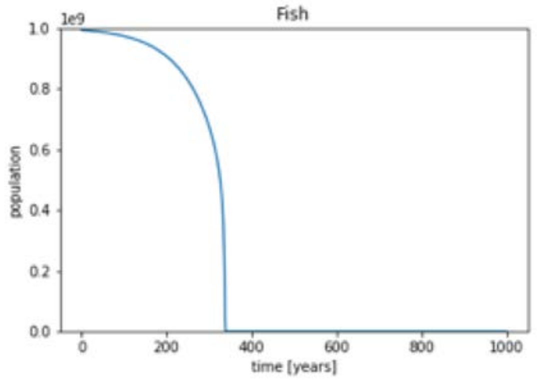


Collapse



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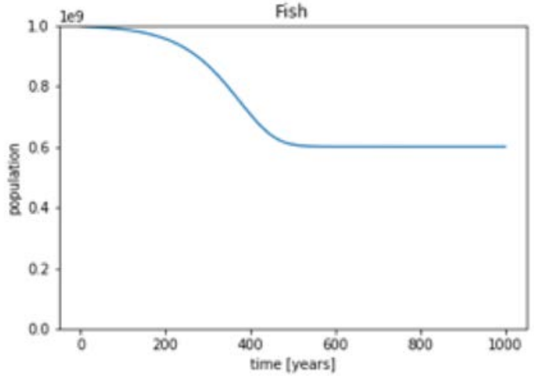

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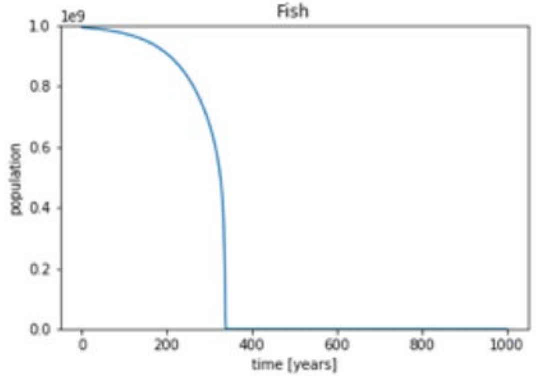
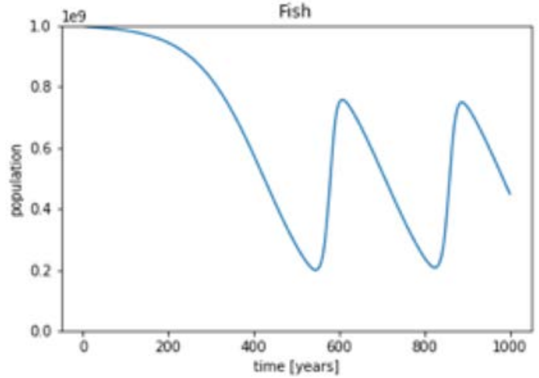
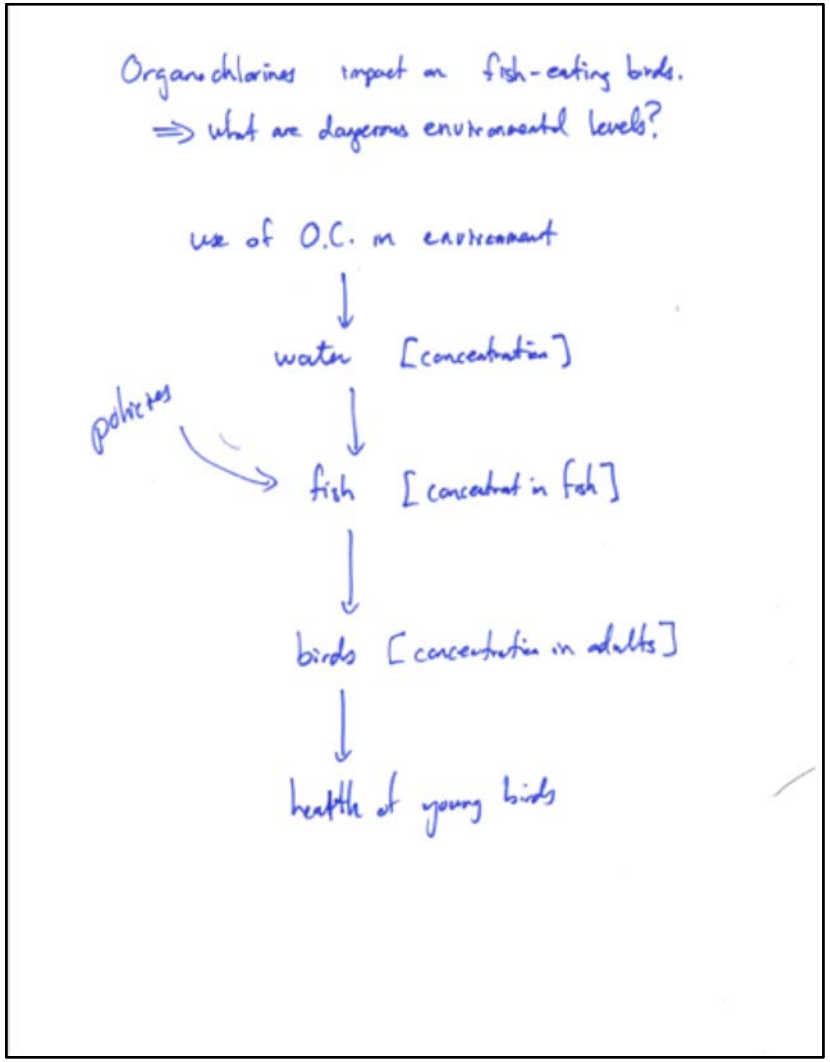
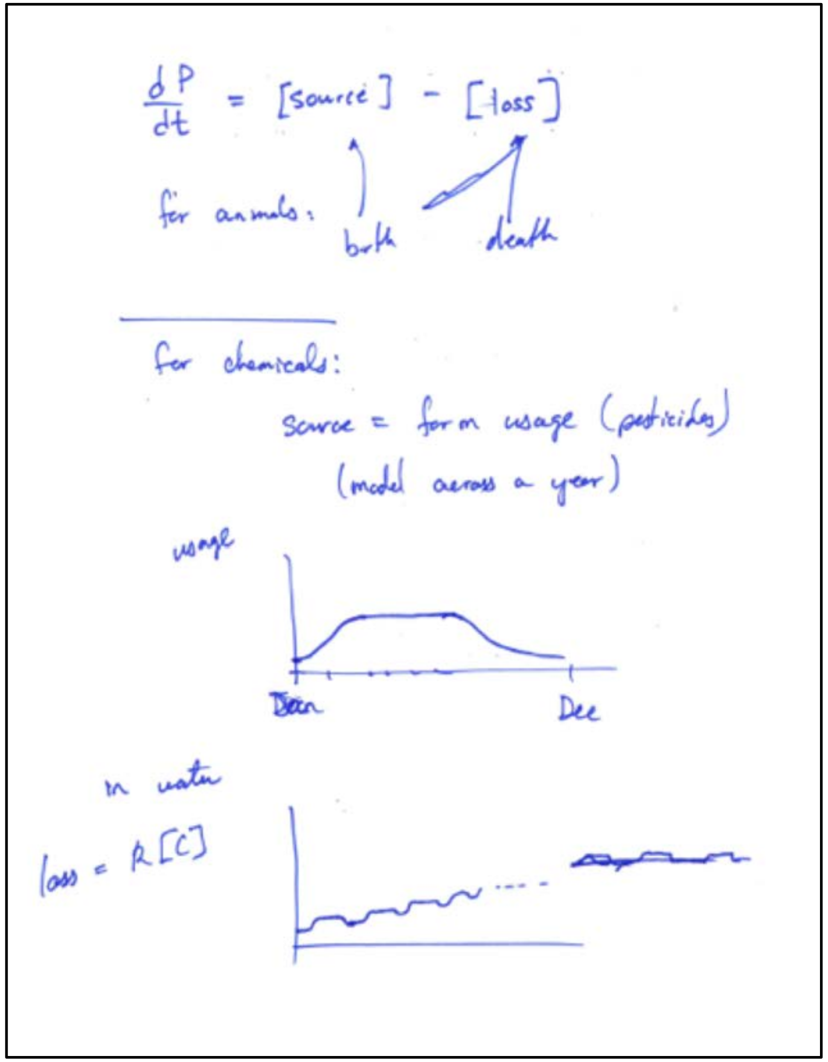


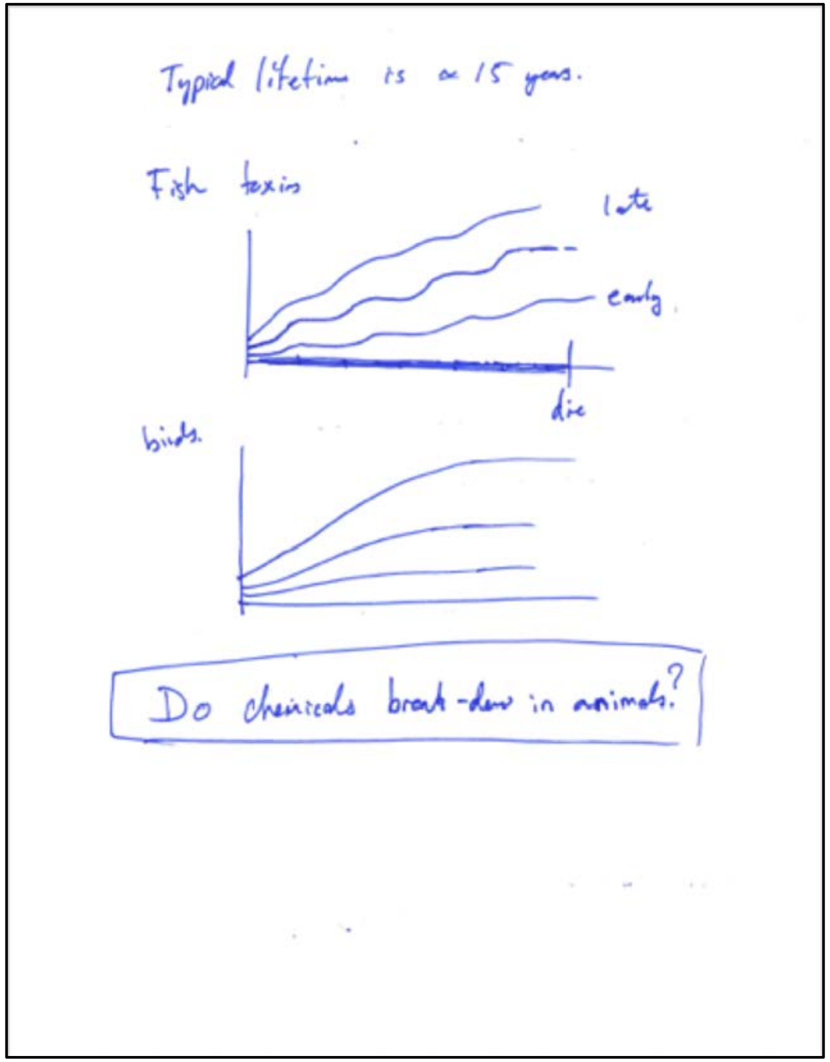
Oscillations



Organo-chlorides & birds







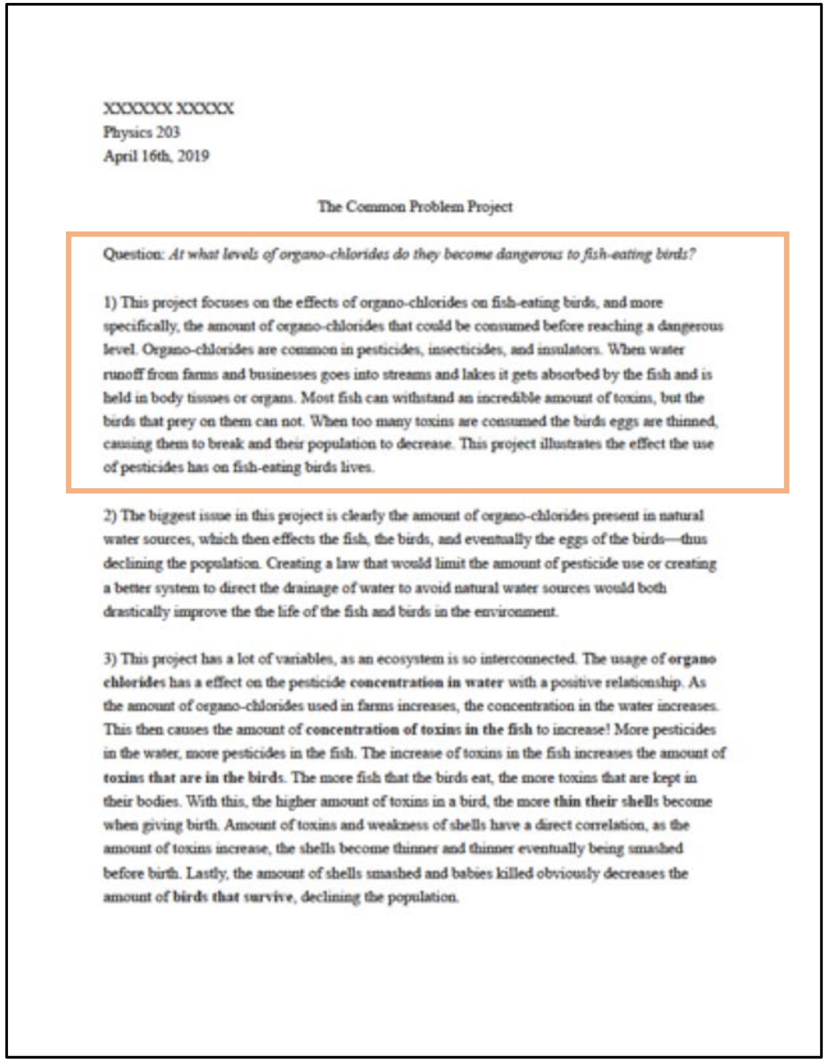
Organo-chlorides & birds

```python
#!/usr/bin/env python3
# -*- coding: utf-8 -*-
"""
This code models the population of birds of prey in response to environmental
pollutants in the form of organo-chloride pesiticides that affect bird birth
rates (shell fragility) through the indirect route of water -> fish
toxification.
"""

import numpy as np
import matplotlib.pyplot as plt
from scipy.signal import savgol_filter as sfilt

# ------------------------------
# simulation setup

# number of days per year
Ndays = 360
# time step in years
dt = 1.0/Ndays
# simulation duration
tsim = 100
# time array
t = np.arange(0,tsim,dt)
# number of entries in array
Nt = len(t)

# number of models to examine
Nmodel = 5

# bird population
P = np.zeros([Nmodel,Nt])
# concentration in birds
B = np.zeros([Nmodel,Nt])
# chemical usage
C = np.zeros([Nmodel,Nt])
# concentration in water
W = np.zeros([Nmodel,Nt])
# concentration in fish
F = np.zeros([Nmodel,Nt])

# ------------------------------
# model parameters

# initial bird population
P0 = 1e4

# max bird population
Pmax = 1e5

#initial pollutant concentration
C0 = 0.0

# critical chemical concentration in birds
Bcrit = 400

# critical chemical concentration in birds
Fcrit = 100

```

```python

for j in range(Nmodel):

    # ------------------------------
    # definition of the chemical use patterns

    t1 = 50
    t2 = 110
    t3 = 181
    t4 = Ndays

    temp0 = np.zeros(Ndays)
    temp0[t1:t2] = (t[t1:t2] - t[t1])/(t[t2] - t[t1])
    temp0[t2:t3] = 1.0
    temp0[t3:t4] = temp[t3-2:0:-1]
    win = 41
    ply = 1
    temp0 = np.abs(sfilt(temp0, win, ply))
    temp0 = np.abs(sfilt(temp0, win, ply))

    temp = np.zeros(Nt)
    for i in range(tsim):
        temp[i*Ndays:(i+1)*Ndays] = temp0


    # model 1: very small usage
    if j == 0:
        A = 3e-3
        C[j,:] = A * temp

    # model 2: small usage
    if j == 1:
        A = 1e-2
        C[j,:] = A * temp

    # model 3: large usage
    if j == 2:
        A = 2e-2
        C[j,:] = A * temp

    # model 4: large usage
    if j == 3:
        A = 4e-2
        C[j,:] = A * temp


    # model 5: large usage
    if j == 4:
        A = 6e-2
        C[j,:] = A * temp


    # ------------------------------
    # simulation

    P[j,0] = P0

    k = 4e-4

```

```python
    # model the build-up in water
    for i in range(1,Nt):
        dW = C[j,i]  - k*W[j,i-1]
        W[j,i] = W[j,i-1] + dW

    # model the build-up in fish
    tau = 6*Ndays
    for i in range(1,Nt):
        dF = 1e-3*W[j,i]  - (1.0/tau) * F[j,i-1]
        F[j,i] = F[j,i-1] + dF

    # model the build-up in birds
    tau = 12*Ndays
    for i in range(1,Nt):
        dB = 1e-3*F[j,i]  - (1.0/tau) * B[j,i-1]
        B[j,i] = B[j,i-1] + dB

    # model the bird populations
    taud = 5*Ndays
    for i in range(1,Nt):
        taub = 1e9
        if B[j,i-1] < Bcrit:
            taub = 2.0 * Ndays * Bcrit / (Bcrit - B[j,i-1])
        dP = (1.0/taub) * (1 - P[j,i-1]/Pmax) * P[j,i-1] - (1.0/taud)*P[j,i-1]
        P[j,i] = P[j,i-1] + dP


# ------------------------------
# data output

plt.figure()
plt.plot(t[0:Ndays]*365.0,temp[0:Ndays])
plt.xlim(0,365)
plt.ylim(0,1.2)
plt.xlabel('time [days]')
plt.ylabel('daily chemical usage [a.u.]')
plt.savefig('daily.png')


plt.figure()
for j in range(Nmodel):
    plt.plot(t,W[j,:])
plt.xlabel('time [years]')
plt.ylabel('water pesticide concentration [ppm]')
plt.xlim(0,100)
plt.ylim(0,100)
plt.savefig('water-chemical.png')


plt.figure()
for j in range(Nmodel):
    plt.plot(t,F[j,:])
plt.xlabel('time [years]')
plt.ylabel('fish pesticide concentration [ppm]')
plt.xlim(0,100)
plt.ylim(0,200)
plt.savefig('fish=chemical.png')
```

Organo-chlorides & birds



XXXXXXX XXXXXX
Physics 203
April 16th, 2019

The Common Problem Project

Question: *At what levels of organo-chlorides do they become dangerous to fish-eating birds?*

1) This project focuses on the effects of organo-chlorides on fish-eating birds, and more specifically, the amount of organo-chlorides that could be consumed before reaching a dangerous level. Organo-chlorides are common in pesticides, insecticides, and insulators. When water runoff from farms and businesses goes into streams and lakes it gets absorbed by the fish and is held in body tissues or organs. Most fish can withstand an incredible amount of toxins, but the birds that prey on them can not. When too many toxins are consumed the birds eggs are thinned, causing them to break and their population to decrease. This project illustrates the effect the use of pesticides has on fish-eating birds lives.

2) The biggest issue in this project is clearly the amount of organo-chlorides present in natural water sources, which then effects the fish, the birds, and eventually the eggs of the birds—thus declining the population. Creating a law that would limit the amount of pesticide use or creating a better system to direct the drainage of water to avoid natural water sources would both drastically improve the the life of the fish and birds in the environment.

3) This project has a lot of variables, as an ecosystem is so interconnected. The usage of **organo chlorides** has a effect on the pesticide **concentration in water** with a positive relationship. As the amount of organo-chlorides used in farms increases, the concentration in the water increases. This then causes the amount of **concentration of toxins in the fish** to increase! More pesticides in the water, more pesticides in the fish. The increase of toxins in the fish increases the amount of **toxins that are in the birds**. The more fish that the birds eat, the more toxins that are kept in their bodies. With this, the higher amount of toxins in a bird, the more **thin their shells** become when giving birth. Amount of toxins and weakness of shells have a direct correlation, as the amount of toxins increase, the shells become thinner and thinner eventually being smashed before birth. Lastly, the amount of shells smashed and babies killed obviously decreases the amount of **birds that survive**, declining the population.

Technical Report:

The report starts by stating the central question:

> *At what levels do organo-chlorides become dangerous to fish-eating birds?*

Then provides further context and a description of the series of connections between agricultural use of organo-chlorides and build-up in birds of prey.

Organo-chlorides & birds

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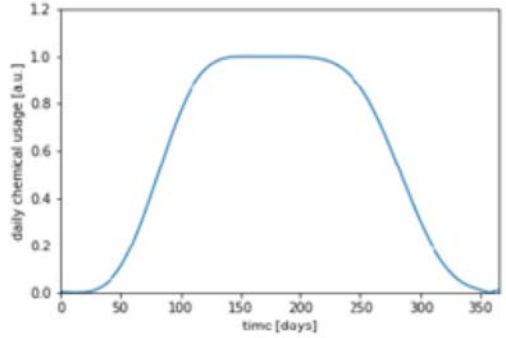
> *At what levels do organo-chlorides become dangerous to fish-eating birds?*

Then provides further context and a description of the series of connections between agricultural use of organo-chlorides and build-up in birds of prey.

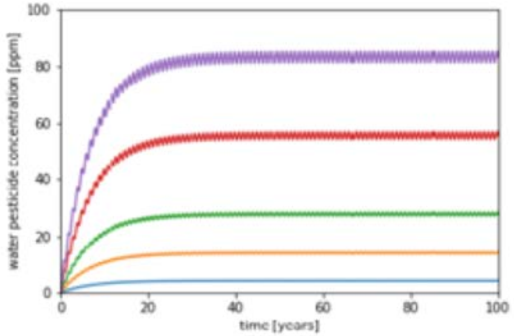
The report then sets the framework for the modeling:

> *Creating a law that would limit the amount of pesticide use or create a better system to direct the drainage of water to avoid natural water sources would both drastically improve the life of the fish and birds in the environment.*

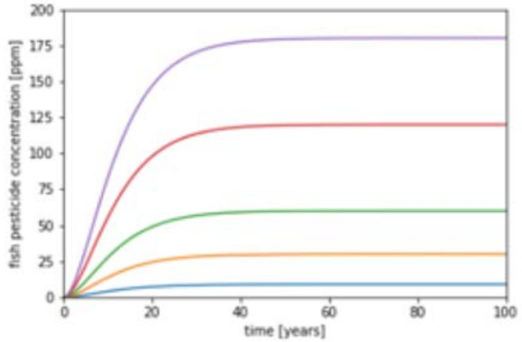
Organo-chlorides & birds



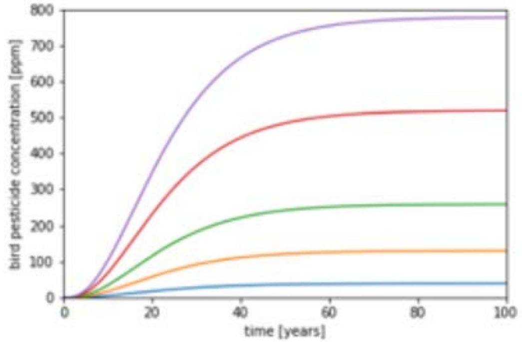
This graph shows the relationship between time and daily chemical usage in a year. The graph has a steady rise to represent spring and summer when more pesticides are used, and a decline during the colder months.



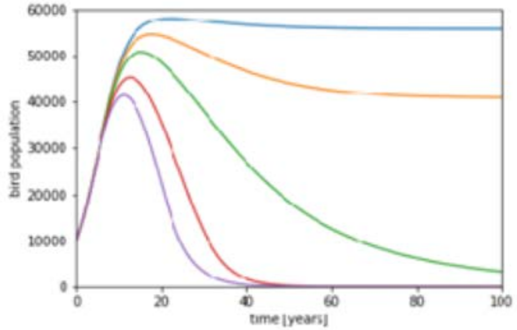
This graph shows the relationship between time and water pesticide concentration. This shows as years go on the amount of pesticides steadily increase. They eventually flatten out, as the amount of pesticides cannot fully replace a lake or big body of water, as some will naturally wash ashore and be taken out by other elements. It has a stair-like trend to represent the amount of pesticides entering the water each year, which fluctuates with the seasons as shown in the graph before.



This graph similarly shadows the previous graph, as the concentration of pesticides in the water increase, naturally the amount of toxins in the fish also increase. However it does not have a staircase effect as the amount of pesticides will not decrease when they are in winter month, it will just contimue to increase as the pesticides are added.



This graph again is directly connected to the previous graph, as the amount of concentration of toxins in the fish increases, the more that goes into the birds bodies. As seen in the graph, as the birds consume more fish they have higher rates of toxins in their bodies as the fish, for the fish are measured on how much is in their system and the birds have multiple fish in their system.



This graph shows the overall effects of the use of organo-chlorides on the population of fish-eating birds. This graph is what means the most in the project, as the population sharply starts to decline. As the birds contimue to eat the fish with the toxins it adds up in their bodies, which affects the thinness of their eggs and the lives of their children. As shown, the first few years seem to be unaffected, but as the eggs contimue to get smashed and not hatch it not only affects that individual bird, but all of the birds that could've been descendants as well. This is shown by the sharp decline when the population of the birds starts low and the lack of incline for all predictions. The affect of organo-chlorides on birds is shown as clearly detrimental in this graph.

5. With this data there are two opposing views that the information can be involved in. There's an environmentalist standpoint, which would concerns the amount of birds that are dying from unnatural causes. The population decline of fish-eating birds doesn't just happen in one specific area, but is seen all around the U.S. and in various other countries. The decline of the birds not only is a danger to them, but also the ecosystem around them as there are much less predators of the fish and prey for other animals. To help fix this situation, would be to control the runoff of the organo-chlorides and ensure none entered any natural water source, or to create a pesticide that will be non-toxic to the birds. The latter would be much harder to accomplish, so the most realistic solution would be to create a way to dispose of the runoff, or to limit the amount of pesticide usage, so although it would still have effects, they would be much smaller.

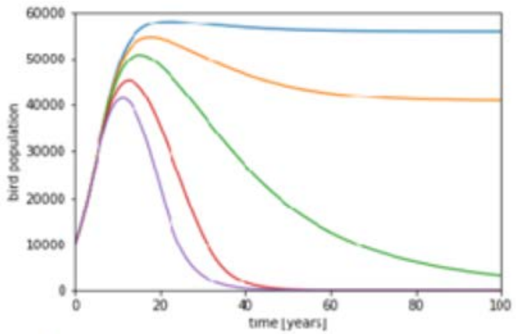
However, limiting the use of pesticides would affect farmers greatly. By limiting their use, it would be most likely that less of their crops would survive, giving them less money and putting them. in more of an economic hardship. Although the pesticides are harming fish and birds, it is more beneficial for the farmers and businesses to contimue to use pesticides to support their own lifestyle.

Overall, I believe the majority of people would side with the environmental argument with this information, the people directly involved with the use of pesticides would hold an opposing position.

Organo-chlorides & birds

The report concludes with the most important graph that shows the culminating effects of organo-chlorides on a bird-of-prey population for different levels of usage.

> *… there are two opposing views…*
>
> *There's the environmental standpoint, which concerns the number of birds that are dying from unnatural causes…*
>
> *However, limiting the use of pesticides would affect farmers greatly…*



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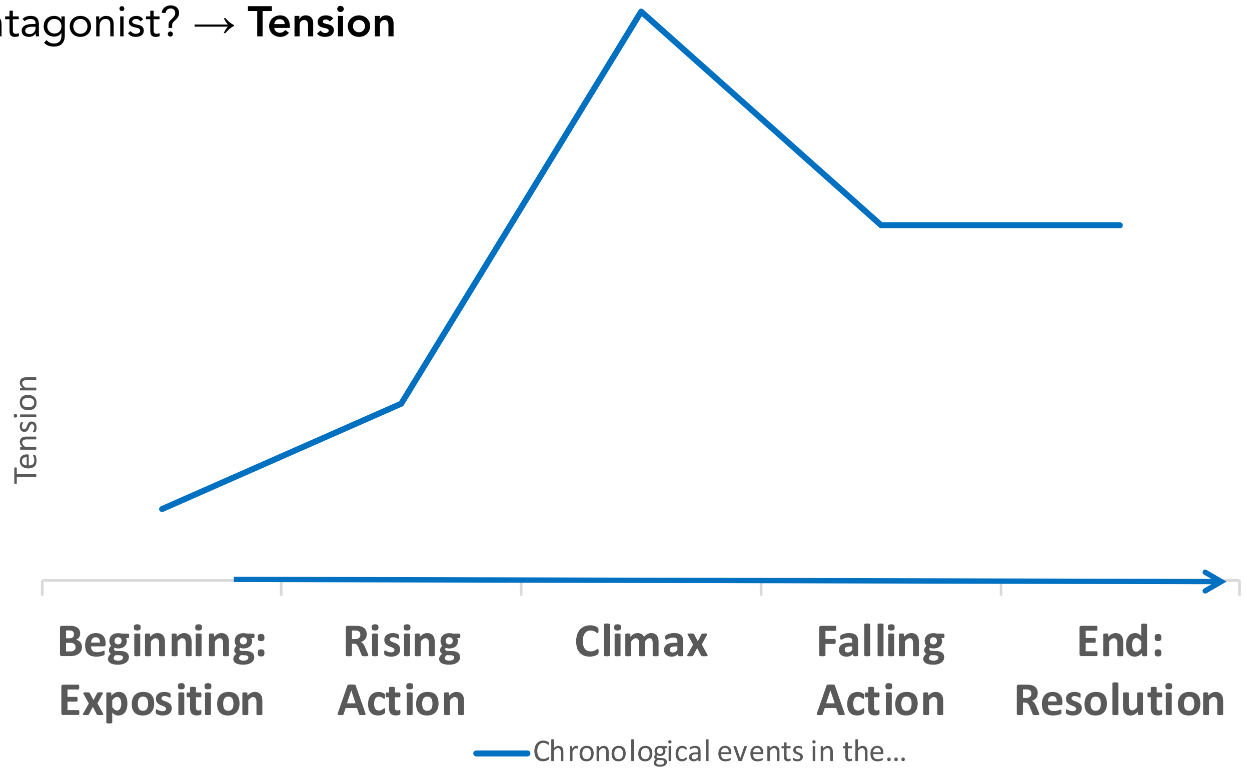
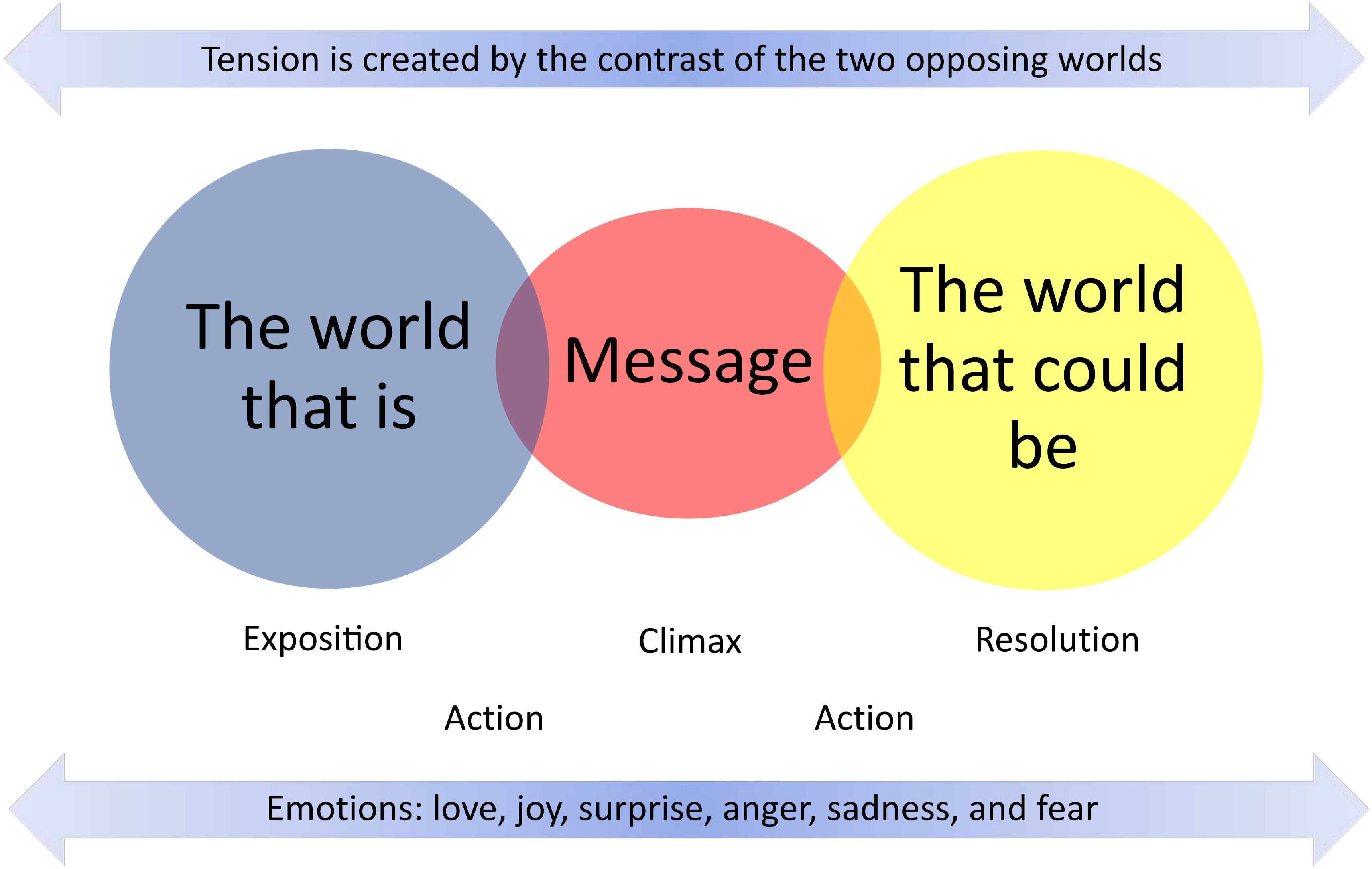
Linear visual narrative structure for time-based media model

Who, Where, What?
Where and when does the plot take place → **Tone**
Who are the protagonist and antagonist? → **Tension**
What is at stake? → **Value**



Freytag pyramid, a technique of the five step dramatic structure

Single image narrative model



Design process

DESIGN THINKING

Design students brainstorming in class

Data Generation

↓

Data Analysis

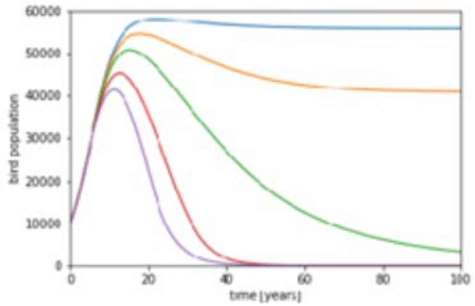
↓

Information (interpretative data)
Concept Development

↓

Infographics (visualized data)
Telling the story of the data

Organo-chlorides & birds



This graph shows the overall effects of the use of organo-chlorides on the population of fish-eating birds. This graph is what means the most in the project, as the population sharply starts to decline. As the birds continue to eat the fish with the toxins it adds up in their bodies, which affects the thinness of their eggs and the lives of their children. As shown, the first few years seem to be unaffected, but as the eggs continue to get smashed and not hatch it not only affects that individual bird, but all of the birds that could've been descendants as well. This is shown by the sharp decline when the population of the birds starts low and the lack of incline for all predictions. The affect of organo-chlorides on birds is shown as clearly detrimental in this graph.

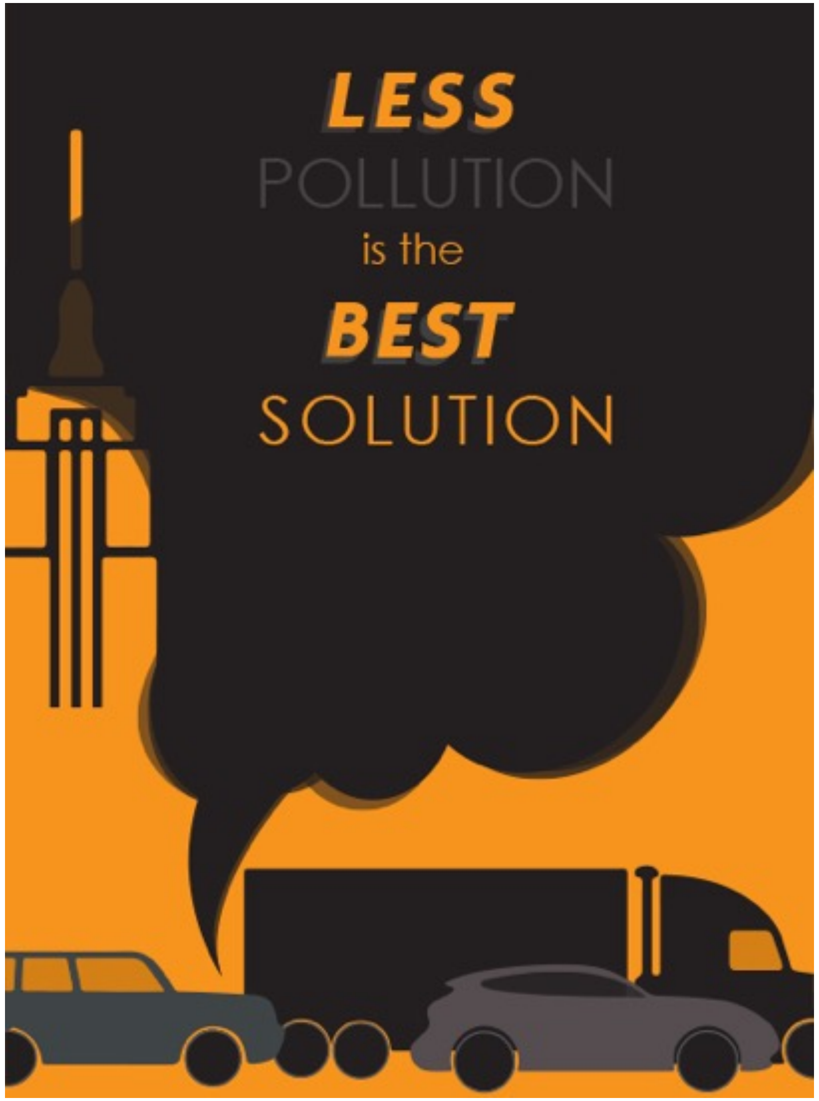
5. With this data there are two opposing views that the information can be involved in. There's an environmentalist standpoint, which would concerns the amount of birds that are dying from unnatural causes. The population decline of fish-eating birds doesn't just happen in one specific area, but is seen all around the U.S. and in various other countries. The decline of the birds not only is a danger to them, but also the ecosystem around them as there are much less predators of the fish and prey for other animals. To help fix this situation, would be to control the runoff of the organo-chlorides and ensure none entered any natural water source, or to create a pesticide that will be non-toxic to the birds. The latter would be much harder to accomplish, so the most realistic solution would be to create a way to dispose of the runoff, or to limit the amount of pesticide usage, so although it would still have effects, they would be much smaller.

However, limiting the use of pesticides would affect farmers greatly. By limiting their use, it would be most likely that less of their crops would survive, giving them less money and putting them. in more of an economic hardship. Although the pesticides are harming fish and birds, it is more beneficial for the farmers and businesses to continue to use pesticides to support their own lifestyle.

Overall, I believe the majority of people would side with the environmental argument with this information, the people directly involved with the use of pesticides would hold an opposing position.

Student projects

Student projects

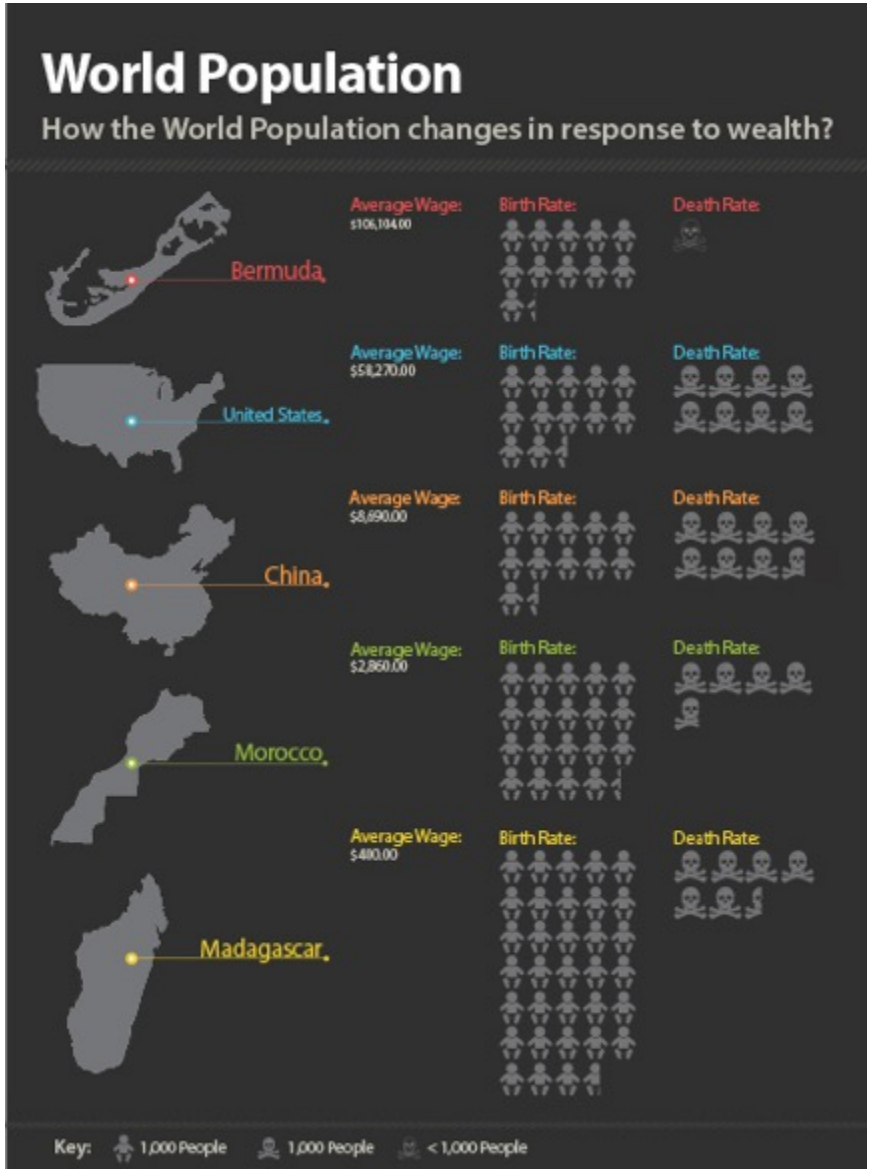


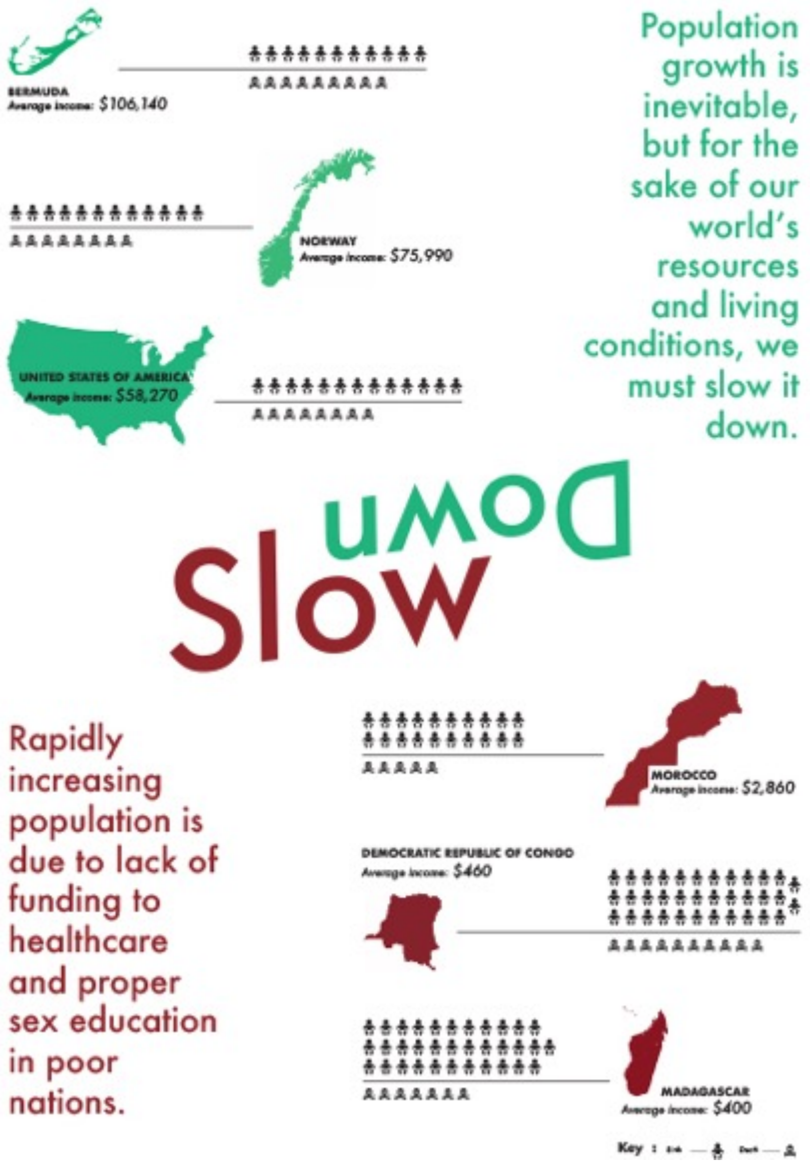
Student projects

Student projects

Student projects

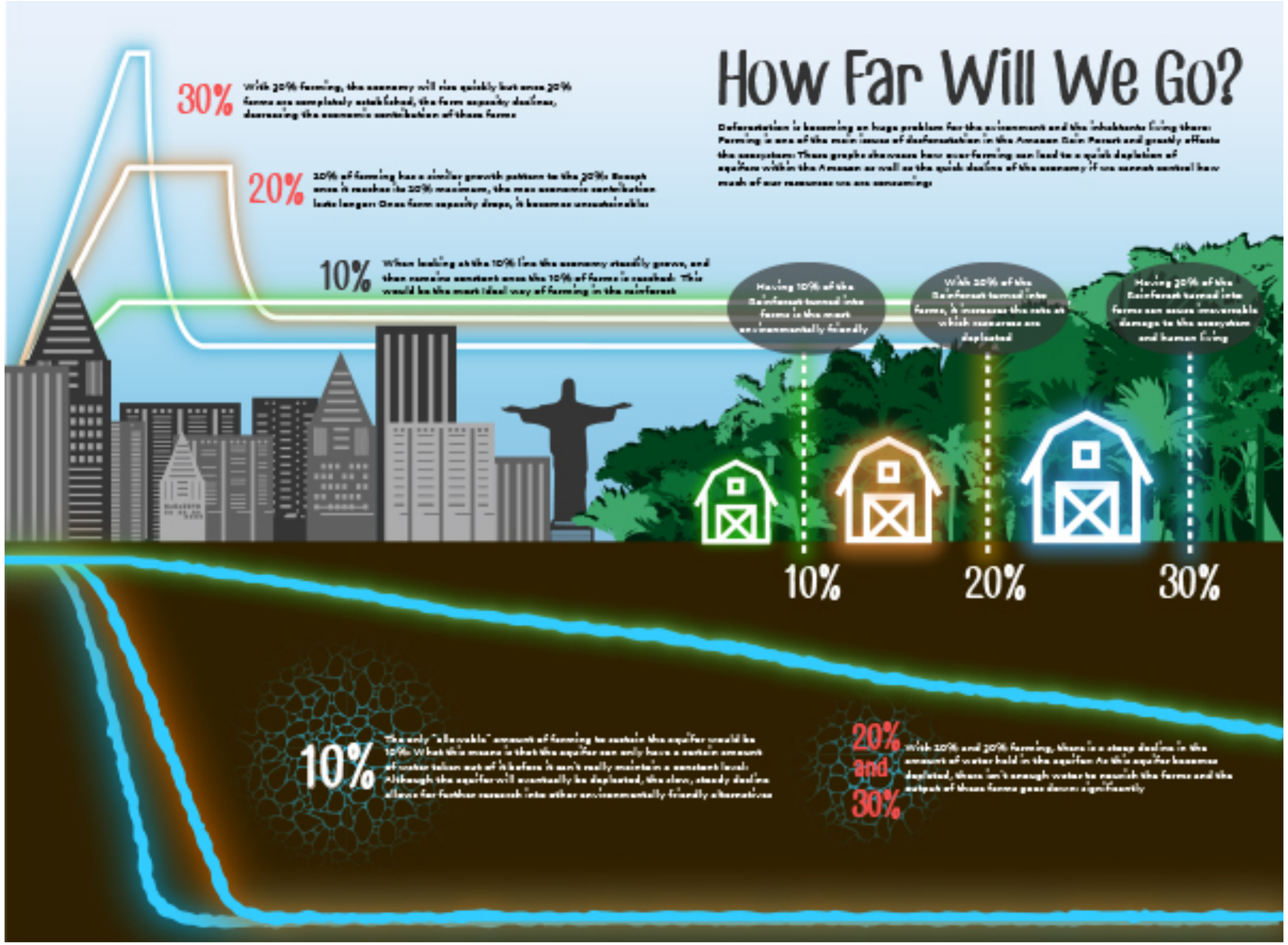
SUNY Cortland





Student projects

SUNY Cortland



Student projects

Exhibition

CONNECTIONS

Connections

Student learning outcomes

Design students

- Translate scientific data (quantitative information) into visual forms
- Use information graphics skills: Use color coded charts, maps, time-lines, or diagrams, and create a legend or key
- Apply visual narrative techniques: to tell the story that is embedded in the data and contextualize the phenomena
- Communicate and collaborate online in a multidisciplinary environment

Physics students

- Visualize the series of connections required in a complex model
- Translate a series of statements about interactions into equations
- Define a set of simulation parameters that effectively illustrate a point
- Communicate findings in a technical report.