

# Interdisciplinary Science Instruction



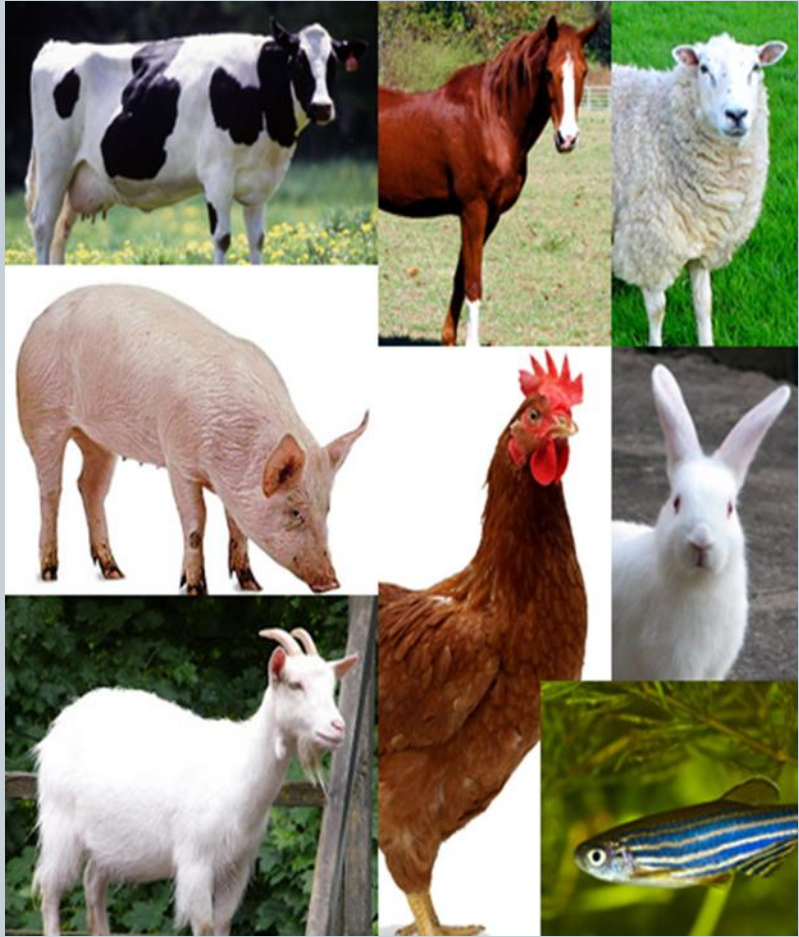
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***“Our education system is a second-rate, factory-style organization, pumping out obsolete information in obsolete ways. [Schools] are simply not connected to the future of the kids they’re responsible for.”***

Alvin Toffler









# Why are species endangered?

## Hunting



Cape fox

## Over-fishing



Southern bluefin tuna

## Invasive species



Kakapo

## Pollution



African penguins

## Pet trade



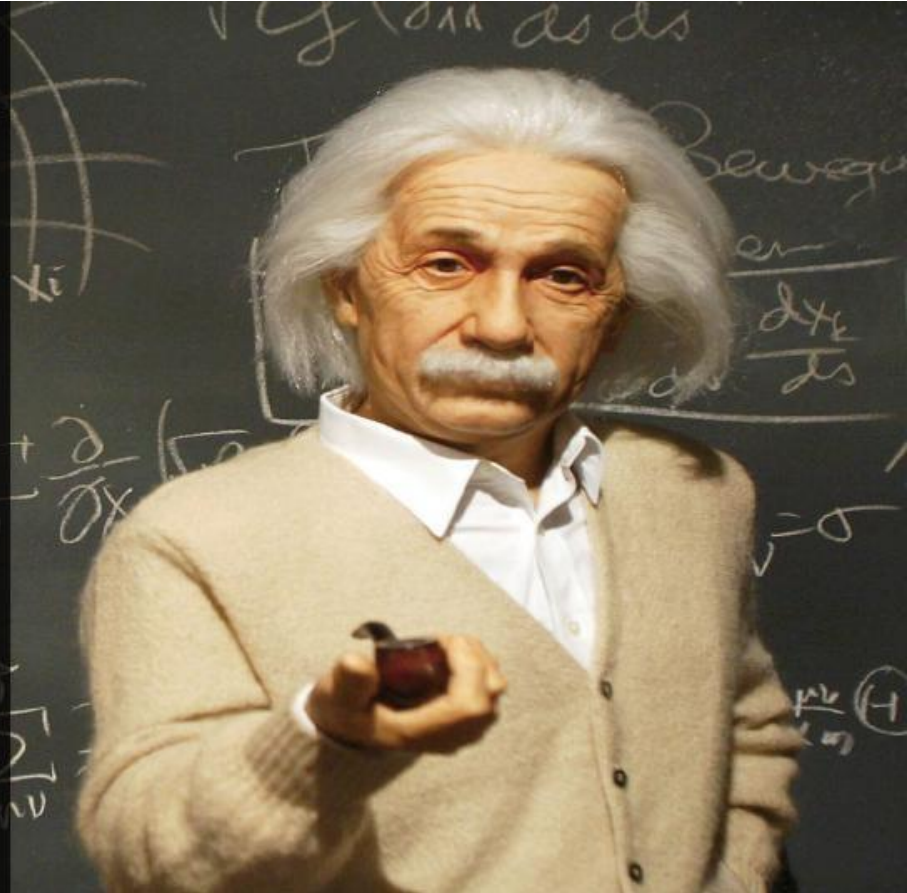
Siamang

## Habitat loss



Golden-crowned sifaka

“It is the supreme art  
of the teacher to  
awaken joy in creative  
expression and  
knowledge”



# What is integration?



- Sometimes educators use the terms integrated, interdisciplinary and thematic synonymously.
- Lederman and Niess (1977) defined **integrated** as a blending in which the separate parts are not discernible. They use the metaphor of **tomato soup**; you cannot discern the tomatoes in the soup.
- They define **interdisciplinary** as a mixture of subjects connected but still identifiable. The metaphor they use is **chicken noodle soup**; it is a soup but you can still recognize the broth, chicken and noodles.
- Jacobs (1988) defines **interdisciplinary** as a “**knowledge view and curriculum approach** that consciously applies methodology and language from **more than one discipline** to examine a central theme, issue, problem, topic or experience.



# What is integration?



- Finally, Lederman and Niess (1997) define **thematic** as a **unifying topic** or subject transcending traditional subject boundaries.
- The word **integrated** to define the **crossing of subject matter** boundaries.

## **A Word of Warning**

- Lonning and DeFranco (1977) argue that integration can be justified only when connecting subjects **enhances the understanding** of the.
- In other words, teachers should not force integration for the sake of integration.

# An example of Curriculum Integration



- The driving question, “**What kinds of insects live in our neighborhood?**” offers many opportunities for teachers to integrate the curriculum:
- In science, students can study camouflage, metamorphosis, classification, body structure, and predator/prey relationships.
- In mathematics students might investigate the area of an insect’s territory. They might graph the number of insects found in different areas of the playground or graph the weight of insects during the different stages of development.
- They might use ratio and proportion to contrast the weight of an ant with the mass it can carry. Students calculate the length of tunnels that ants build. They might explore the geometric shapes found in nature’s insect populations or find the average number of days it takes for insects to complete metamorphosis.

# An example of Curriculum Integration



- Social studies are involved when students learn about the historical impact of insects (such as locusts) and the development of insecticides to limit insect populations. Students might study the cultural behaviors (such as eating insects) of people in other countries.
- Literacy is involved when students write reports, communicate findings, give each other feedback, and read and discuss insect-related stories.
- What follows are some stories that could be used in an insect-science-language arts activity project.
- The very hungry caterpillar
- Of bugs and beasts
- Where butterflies grow

# What is interdisciplinary approach?



- An approach to curriculum integration that generates an understanding of **themes and ideas** that **cut across disciplines** and of the **connections between different disciplines** and their **relationship to the real world**.
- It normally emphasizes **process and meaning** rather than **product and content** by combining contents, theories, methodologies and perspectives from two or more disciplines.

# What is multidisciplinary approach?



- An approach to curriculum integration which focuses primarily on the different disciplines and the diverse perspectives they bring to illustrate a topic, theme or issue.
- A multidisciplinary curriculum is one in which the **same topic** is studied from the **viewpoint of more than one discipline**.
- Frequently multidisciplinary and cross-disciplinary are used as synonyms describing the aim to cross boundaries between disciplines.

# What is transdisciplinary approach?



- An approach to curriculum integration which dissolves the boundaries between the conventional disciplines and organizes teaching and learning around the construction of meaning in the context of real-world problems or themes.

# What is Knowledge integration?



- The knowledge integration perspective for interdisciplinary teaching emphasizes the role of teachers because it is their responsibility to encourage students to establish a successful conceptual change by integrating prior knowledge with new ideas and practices, which inevitably results in a more coherent understanding of science and math.
- As a result, KI theory provides as rationale for the guiding mechanisms, which pertains to acquisition, connection, and redefinition of the learners knowledge under a constructivist view of learning.

# What is Knowledge integration?



- Lunn and Eylon (2006) conceptualized four general processes that can promote KI: (1) eliciting current ideas, (2) adding new ideas, (3) distinguishing among ideas, and (4) sorting ideas.
- Linn, Slotta, Terashima, Stone and Madhok (2010) adapted the framework of the processes KI and developed five processes of KI, which are as follows:
  - (1) Eliciting ideas: The process of learning elicit students' prior ideas, backgrounds, and experiences, which enable them to create relevant connections to new ideas from already existing ideas in a learning context.



# What is Knowledge integration?



- 2) Adding new ideas: Learning environments traditionally aim to add ideas through some kind of learning activity, which allows learners to explore the relationships among all of their existing and new ideas to eventually form connections between them.
- 3) Distinguishing ideas: after adding ideas, students are required to carefully distinguish productive ideas from unproductive ones to connect scientifically relevant and normative ideas.
- 4) Sorting out ideas: Students need opportunities to prioritize the numerous, often contradictory, existing ideas and sort out the various connections among these ideas to develop a coherent understanding of the subject.
- 5) Developing criteria: Students need to develop criteria for the relationships between ideas. The criteria encourage students to coordinate productive ideas of target phenomena and demonstrate a coherent and durable scientific understanding.

# What is Knowledge integration?



Shen, Liu and Sung (2014) considered three special processes in interdisciplinary knowledge integration: translation, transfer and transformation.

1. Translation process involves specialized terminologies and jargon developed within each discipline, which should be interpreted differently in other disciplines.
2. Transfer refers to the process where students apply explanatory models and concepts learned from one disciplinary context to another.
3. Transformation indicates the potential to apply explanatory models and concepts learned from one discipline to a new system in a different discipline.

# What is Knowledge integration?



Thus, the KI process implies that a “deep transfer” of the knowledge of teachers is crucial step in drawing on their interdisciplinary understanding than only focusing on adding new ideas between disciplines.

The transformation process requires both integration of relevant disciplinary knowledge and the appropriate transfer.

Linn (1995) suggested a method of teaching called “scaffolded knowledge integration”, which can encourage students to develop interdisciplinary understanding, especially of a complex domain , by enabling them to develop a more coherent scientific literacy.

# Why teach with an Interdisciplinary Approach?



1. Interdisciplinary Teaching Increases Student Learning
  - Repko (2009) asserts that interdisciplinary instruction fosters advances in cognitive ability and other educational researchers (Kavaloski 1979, Newell 1990, Field et al. 1994, Vess 2009) have identified a number of distinct educational benefits of interdisciplinary learning including gains in the ability to:
    - Recognize bias
    - Think critically
    - Tolerate ambiguity
    - Acknowledge and appreciate ethical concerns

# Why Teach with an Interdisciplinary Approach?



## a. **Interdisciplinary Teaching Helps Students Uncover Preconceptions or Recognize Bias**

- Interdisciplinary instruction allows us to understand our preconceptions of "what is" and the framework by which we arrived at "what is." It also fits with recent advances in learning science about how to foster learning when students bring powerful pre-existing ideas with them to the learning process. Bransford (2000) drawing on scientific research findings from the fields of neuroscience, cognitive science, social psychology, and human development asserts that interdisciplinary forms of instruction,
- Help students overcome a tendency to maintain preconceived notions. This is accomplished by recognizing the source of the preexisting understandings they arrive with, and by introducing students to subject matter from a variety of perspectives that challenge their existing notions. Interdisciplinary instruction accomplishes this goal in two ways. First, by helping students identifying insights from a range of disciplines that contribute to an understanding of the issue under consideration. Second, by helping students develop the ability to integrate concepts and ideas from these disciplines into a broader conceptual framework of analysis.
- **The Gain** - when students put aside their pre-existing notions they position themselves to learn facts more readily and are more open to adopting a range of methodologies that promote understanding. Teachers can thus spend more time exploring issues with them that promote *significant learning* (for information on *significant learning* see the section below entitled Interdisciplinary Teaching Promotes *Significant Learning*).

# Why Teach with an Interdisciplinary Approach?



## **b. Interdisciplinary Teaching Helps Advance Critical Thinking and Cognitive Development**

- Interdisciplinary instruction helps students develop their cognitive abilities - brain-based skills and mental processes that are needed to carry out tasks. Allen Repko (2009) identifies a number of cognitive attributes that interdisciplinary learning fosters. He asserts, that interdisciplinary learning helps students,
- Acquire Perspective-Taking Techniques (Baloche, Hynes, and Berger 1996) - the capacity to understand multiple viewpoints on a given topic.
- **The Gain** - students develop an appreciation of the differences between disciplines on how to approach a problem and their discipline specific rules regarding viable evidence. This leads to a broader understanding of the issue under investigation.
- Develop Structural Knowledge - both *declarative knowledge* (factual information) and *procedural knowledge* (process-based information).
- **The Gain** - each of these forms of knowledge are needed to solve complex problems. Thus, as students enhance their knowledge formation capacity, teachers can engage them in conversations dealing with more complex issues.
- Integrate conflicting insights from alternative disciplines.
- **The Gain** - a host of disciplines attempt to understand the same or related problems, but each disciplines adopts different mechanisms of analysis and approaches to evaluating the viability of their insights. Obtaining a clear understanding of problems with roots in multiple disciplines requires the capacity to integrate ideas and this skill is advanced by interdisciplinary learning.

# Why Teach with an Interdisciplinary Approach?



## c. Interdisciplinary Teaching Helps Students Tolerate or Embrace Ambiguity

- Interdisciplinary instruction helps students understand why conflicts commonly arise over; the causes and consequences of an issue and, the ideal way for policy to address the issue of concern. When learning is confined to a single disciplinary perspective ambiguity is often considered either a shortcoming of the analytical framework or evidence that assumptions need to be adopted to provide a clear prediction.
- **The Gain** - interdisciplinary instruction advances the notion that ambiguity results from alternative perspectives on issues that are advanced by different disciplines rather than a shortcoming of a particular discipline. Thus, students acquire a better understanding of the complexity of problems of interest and the associated challenges of solving them.

# Why Teach with an Interdisciplinary Approach?



## d. Interdisciplinary Teaching Helps Students Appreciate Ethical Dimensions of Concerns

- Interdisciplinary instruction helps students understand that there are ethical dimensions to most issues of concern. Ethical considerations entail moral concerns which means accounting for perceptions of right vs. wrong, good vs. bad, and the provision of justice. Many disciplines steer clear of such subjective phenomena and confine their analysis to more objective factors in an effort to be scientific.
- **The Gain** - interdisciplinary instruction promotes the integration of ideas from relevant disciplines - including moral philosophy when exploring an issue so ethical considerations are often part of an interdisciplinary examination of an issue. This is useful since or perspectives on a question, and policy considerations are likely to include discussion and valuation of ethical factors.



# Why Teach with an Interdisciplinary Approach?



## 2. Interdisciplinary Teaching Promotes *Significant Learning*

- *Significant Learning* (Fink, 2003) takes place when meaningful and lasting classroom experiences occur. According to Fink when teachers impart students with a range of skills, and insights about the educational process that students will see as meaningful and salient to them they promote student engagement in the learning process and greater learning occurs. Fink identifies 6 elements of the educational process that lead to *significant learning* and each of these is a common feature of interdisciplinary forms of instruction.
- **Foundational Knowledge** – acquiring information and understanding ideas
- **Application** – acquiring an understanding of how and when to use skills
- **Integration** – the capacity to connect ideas
- **Human Dimension** - recognition of the social and personal implications of issues
- **Caring** – acknowledgment of the role of feelings, interests, and values
- **Learning *How-to-Learn*** – obtaining insights into the process of learning
- **The Gain** - Interdisciplinary instruction fosters the acquisition of foundational knowledge, promotes integration of ideas from multiple disciplines and provides insight on how to apply knowledge all of which advance a students understanding of how to learn. Moreover, students are encouraged to account for the contribution of disciplines that highlight the roles of caring and social interaction when analyzing problems. Thus, the very structure of interdisciplinary learning is consistent with the core features of significant learning, so students are expected to find interdisciplinary education engaging and thus an effective way to advance their understanding of topics under investigation.

# Why Teach with an Interdisciplinary Approach?



## 3. Interdisciplinary Teaching Promotes Understanding when Students Learn in Heterogeneous Ways

- Prominent psychologist Howard Gardner (1983) established that students bring multiple forms of intelligence to the learning process. As a result, given that students are heterogeneous in their learning styles and have diverse backgrounds, interests, experiences, talents, and values, he believes that drawing on a broad array of frameworks and methodologies will enhance student engagement, and thus learning.
- **The Gain** - Interdisciplinary instruction opens academic conversations to ideas from a range of disciplines so all students should be able to relate and contribute to the dialogue. Thus, the likelihood of connecting with the full array of the students in the classroom is enhanced by interdisciplinary learning.

# Why Teach with an Interdisciplinary Approach?



## 4. The World is Interdisciplinary

- According to The National Council for Teachers of English (NCTE 1995) "educational experiences are more authentic and of greater value to students when the curricula reflects real life, which is multi-faceted rather than being compartmentalized into neat subject-matter packages." In their view, real-world problems are complex, so no single discipline can adequately describe and resolve these issues. Therefore, they are not surprised that interdisciplinary forms of learning are prevalent and growing in abundance and stature throughout higher education (Edwards, 1996, Gaff & Ratclif, 1997, and Liein, 1996).
- **The Gain** - students recognize that there are a variety of perspectives what can be brought to bear in an effort to understand most issues. Thus, they find interdisciplinary forms of exploration more compelling, which promotes engagement and learning.
- In summary, the emerging popularity of interdisciplinary teaching is grounded in the student gains that various researchers have identified.

# Why Teach with an Interdisciplinary Approach?



## 5. Interdisciplinary Teaching is Not Too Costly and It's Rewarding

Moving from a disciplinary oriented form of teaching to being an interdisciplinary educator is not too costly for four reasons.

First, most educators are familiar with the methodologies and empirical practices of related disciplines so acquiring the necessary cross disciplinary knowledge to become an interdisciplinary teacher will not be overly stressful or time consuming.

Second, most educators are familiar with task modeling - an instructional strategy that promotes learning through observation - which is fundamental to interdisciplinary teaching since most students are unfamiliar with interdisciplinary approaches to learning, so instructors do not have to learn an entirely new form of pedagogy.

Third, synthesis of insights from across disciplines, the most demanding element of interdisciplinary teaching, is an activity that most scholar-educators have engaged in previously or can learn to do with modest effort. Finally, instructors can determine the share of the course that is interdisciplinary, so they insert into their course the level of interdisciplinarity that is ideal for them given their experience with this form of teaching and the nature of the course they are leading.

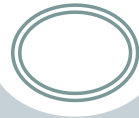
# Why Teach with an Interdisciplinary Approach?



## 6. Interdisciplinary Thinking and Four Cognitive Abilities

- Interdisciplinary teaching is a demanding enterprise. Therefore, educators must believe there are sufficient gains for their students to justify the investments they must make and the stresses they will face as they expand their instructional approach. Allen Repko (2009), Director of the Interdisciplinary Studies Program for the School of Urban and Public Affairs at the University of Texas at Arlington, identifies four cognitive abilities (i.e., brain-based skills and mental processes that are needed to carry out tasks) that interdisciplinary learning fosters which helps to explain the emerging popularity of interdisciplinary inquiry;
- Perspective-Taking Techniques (Baloche, Hynes, and Berger 1996)
  - This refers to the capacity to understand multiple viewpoints on a given topic including an appreciation of the differences between disciplines and especially their perspectives on how to approach a problem and their rules of evidence.

# Why Teach with an Interdisciplinary Approach?



- **Development of Structural Knowledge**
  - This is composed of two elements, declarative knowledge (i.e., factual information) and Procedural Knowledge (i.e., process-based information), which are needed to solve complex problems.
- **Integration of conflicting insights from alternative disciplines**
  - When ideas from a variety of disciplines are embraced when investigating an issue alternative perspectives and predictions often arise. The intellectual challenge is to find ways to account for these which entails careful and creative thinking rather than revert to a single disciplinary explanation.
- **Interdisciplinary Understanding**
  - This entails seeing an issue from an array of perspectives and recognizing how each of the alternative approaches influences one another.

# How to Make Your Teaching/ Classroom Interdisciplinary



Effective design and implementation of interdisciplinary classroom explorations, regardless of the level or type of class, entails six key steps.

**1. Pre-Instructional Planning** - Prior planning establishes the topics to be examined in an interdisciplinary manner, and allows the educator to acquire the requisite knowledge, and to develop an action plan--codified in a set of notes that may include open ended questions--to guide the classroom experience.

# How to Make Your Classroom Interdisciplinary



**2. Introduce the Methodology to Students** - Explain to students the nature of interdisciplinary, rather than discipline based learning. Impress upon them the importance of integrating insights and approaches from multiple disciplines to form a framework of analysis that will lead to a rich understanding of complex questions. Make clear that you will be modeling how to approach an issue in an interdisciplinary manner, and that ultimately they will be asked to master this skill. Allay student fears by noting they will be given assignments that help them reach this objective by practicing approaching topics as interdisciplinary investigators.

**3. Take it to the Classroom** - Model how to explore questions from an interdisciplinary perspective. Repko and Welch (2005), leading figures in the movement to promote interdisciplinary education, identify 9-steps to follow to engage students in an interdisciplinary exploration.



# How to Make Your Classroom Interdisciplinary



- 4. Practice Interdisciplinary Thinking** - Students practicing interdisciplinary thinking by reenacting what they observe in the classroom is an effective way to acquire this higher order cognitive skill. Students can be assigned the task of rethinking an issue discussed in a discipline based manner in class by bringing another discipline to bear and then attempting to synthesize and integrate their analysis.
- 5. Provide Feedback** - Extension and interdisciplinary position papers should be evaluated regularly using a rubric.
- 6. Assessment** - Students should engage in self evaluation periodically by rating their ability to: set out the structure of multiple disciplines that are well suited to the problem of interests, synthesize insights from multiple disciplines, and integrate ideas across disciplines. This information will allow them to gauge their progress, identify challenging areas, to seek help, and set goals for improvement.

# Challenges Facing Interdisciplinary Teachers



Educators who successfully introduce interdisciplinary forms of instruction into the classes they lead must overcome a number of hurdles that can be surmounted by interested educators. Those who make the transition must:

- **Become sufficiently knowledgeable** in relevant related disciplines to be able to comfortably introduce and guide an interdisciplinary investigation.
- **Find the appropriate level of interdisciplinary complexity.** For most students, integrating introductory level concepts from multiple disciplines will add sufficient depth and breadth to their understanding.
- **Convince students** that the additional costs of thinking in an interdisciplinary fashion are worth it.

# Challenges Facing Interdisciplinary Teachers



- **Avoid polarity** which occurs when instructors in an interdisciplinary setting become territorial about their content area and its role in the analysis because they are threatened by another discipline's viewpoint.
- **Offer a balanced examination** of theoretical and methodological assumptions underlying each discipline that is part of the interdisciplinary examination (Cowan et al. 1997).
- **Promote the synthesis of ideas** from a variety of disciplines leading to an integrated form of analysis. Acquiring the ability to synthesize, a higher-order cognitive skill in Bloom's (1956) taxonomy and a key objective of interdisciplinary teaching is taxing for students. Moreover, helping students learn to synthesize is the greatest challenge for an educator to navigate or overcome on the path to interdisciplinary examination of topics. Learn more about [Blooms Taxonomy](#) and its link to synthesis and interdisciplinary teaching.

# Challenges Facing Interdisciplinary Teachers



- A confounding issue is that there are often fundamental contradictions between disciplines regarding methodology and assumptions leading to divergent insights and predictions. Thus, although an interdisciplinary examination is conducted in a systematic fashion, it is often difficult to generate a coherent framework of analysis which is ideal. However, reflection on *why* a cohesive framework is elusive is a vital part of interdisciplinary thinking and should be embraced when appropriate.

# Overcoming the Challenges Facing Interdisciplinary Teachers



- There are a number of strategies and actions an instructor can adopt to facilitate a smooth transition to offering interdisciplinary learning opportunities.
- **Become sufficiently knowledgeable**- read introductory level material on topics to be covered from related disciplines. Talk to colleagues in related disciplines about concepts you will discuss in class to instill confidence that you have a clear understanding of the fundamental ideas.
- **Find the appropriate level of interdisciplinary complexity** - begin with a topic where basic principles from another discipline are sufficient to offer a viable interdisciplinary examination of the topic under consideration. If students are comfortable with this level of analysis, selectively introduce one or more desired additional concepts, and monitor student understanding.
- **Convince students that interdisciplinarity is worthwhile** -during class conversation and in assignments ask students to identify insight they would have missed if they had engaged in a discipline specific investigation of the topic and if the gain is substantial enough to warrant an interdisciplinary examination.
- **Avoid polarity** - incorporate insights from other disciplines that you believe are well suited to enrich student understanding of the topic so that students clearly see that the instructor believes this form of integration is valuable.
- **Offer a balanced examination** - make a conscious effort to present insights from each discipline in a non-hierarchical manner, with the likely exception of choosing one discipline (usually that of the instructor) as the base from which to begin the analysis.

# Overcoming the Challenges Facing Interdisciplinary Teachers



- **Promote the synthesis of ideas** - after modeling interdisciplinary thinking for students, especially how to synthesize and integrate insights from multiple disciplines, it is essential that the instructor ask the students to attempt this activity when new problems are addressed.
  - Do not intervene too quickly, let the students grapple with how to integrate and offer a range of ideas and approaches to reach this end. Consider adopting small group activities to allow students to engage in cooperative learning to become more proficient in integrating insights from a host of disciplines.
  - In small class settings ask students open-ended questions that require them to broach synthesis and integration. Moreover, ask them to identify areas of conflict and cohesion across disciplines. Do not be afraid to follow reasonable pathways, if they turn out to be barren that is part of the way in which students will learn how to integrate.
  - Encourage students to be creative and take risks as they wrestle with the challenges of being more inclusive thinkers.
  - Summarize often, always beginning with the notions that each discipline in isolation would offer. Then identify the potential gains from synthesis and integration, and clarify the options on the table to foster integration.

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