PDP Design Notebook - 2018 Team 13

PDP Design Task: Participants are expected to develop their own lesson plan for an inquiry activity that embodies the three PDP themes: Inquiry, Equity & Inclusion, and Assessment, and integrates research-based understandings of teaching and learning (such as those summarized in *How Learning Works*). Participants work on a team to **design**, **teach**, and **assess** learners in their activity, to pilot, evaluate, and reflect on their work.

The prompts below will help your team think through and document your inquiry activity design work. Please do not delete the prompts (any text in blue). This Design Notebook has been intentionally assembled in a backward fashion so it aligns with how your inquiry design should evolve and the order of the sessions at the Inquiry and Design Institutes. Embedded within this Design Notebook are Design Tools and prompts that can also support your design process.

This shared document is meant to be a collaborative workspace for your design team. Think of it as a place to BRAINSTORM and keep track of your thoughts. Ideas may change over time and we would like to see the documentation of that iterative design process. A first step with your team should be how to distinguish everyone's contributions to this document (ex: color coding).

Throughout your design process, we will ask that your most current design ideas for specific components be updated on your team's Teaching Plan google doc. The deadlines for these items are outlined in the "Design Milestones" table. PDP instructors will provide constructive feedback on the ideas updated in your Teaching Plan, but may refer to this Design Notebook to check on your process and design choice rationale. Ultimately, your final activity design will be transferred to your team's Teaching Plan. We also ask that you post your final materials lists, presentations, handouts, and other files/documents on your team's wiki.

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General Information

Teaching Plan Milestones

At various stages during the design process, Design Teams need to transfer their most current ideas to their Teaching Plan. Refer to the Design Milestone for specific information the PDP staff would like to see at each milestone.

General information about your teaching activity

(some of these items may need to be updated as you move through the design process or even at the end when you are finalizing details)

Activity Name: Machine learning - decision tree learning

Design team members (please indicate your code for distinguishing individual team member's contributions):
GL (in red)
GR (in green)
LA (in black)

Teaching venue:
Akamai PREP #2 Computer Science
UH Hilo, June 17-20, 2018 **(Teaching June 18, 19)**
Discipline: Computer Science

How many learners you expect to teach: ~40 (20 each day)

What you know about learners' level and background: STEM undergrads

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Content Design Tool

PDP Design Team Leaders (DTLs) proposed a content learning outcome and some other preliminary focus points for their team's inquiry activity, and got feedback from PDP staff (with possible further iterations), before their team's first meeting.

DTLs, please copy and paste here your content design tool AFTER your first team meeting but BEFORE the Inquiry Institute.

The proposed concept to focus on on for your activity (e.g. core concept, big idea, etc.)
Machine learning - decision tree learning

Importance or centrality of the concept. Some things to consider: How it might explain many scientific phenomena or support many engineering design choices; how this concept may be connected to other important concepts in your field; how mastery of this concept might contribute to a learner's development of identity as a scientist/engineer.
Decision tree learning (https://en.wikipedia.org/wiki/Decision_tree_learning) is a popular machine learning technique used to solve predictive modeling problems. A decision tree algorithm creates a model that predicts a target variable based on input variables (e.g., predict the type of flower given length and width of the petals and sepals). A tree is "learned" (grown/constructed) by repeatedly splitting on a "best" input variable. Different algorithms use different metrics for determining the "best" split. The goal is to maximize the accuracy of the prediction. In this inquiry learners will learn to analyze and solve a predictive problem using a decision tree algorithm.

Specific to Akamai venue: Akamai interns are increasingly tasked with building algorithms to achieve particular projects with their mentors. More specifically, machine learning is becoming a hot topic and multiple projects want to use machine learning and big data. [Austin Barnes, ISEE/Akamai Workforce Development Program Manager]

The need that supports your choice of this concept (refer to research, direct teaching experience, or assessment results that indicate this concept is challenging for learners).
Refer to STEM content and practices in literature for helpful references.
Expertise in machine learning has become one of the highly demanded skills in the workforce. Many computer software now include libraries that allow users to perform popular machine learning algorithms on custom data easily. Such dependency, without a proper understanding of the underlying algorithm and the tradeoffs associated with the amount of data available, often leads to unreliable and erroneous predictions. While this may mean a loss of profit in e-commerce, it could mean life and death in medical diagnosis.

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In order to maximize a model's prediction accuracy properly, learners will need to make sure that their models do not overfit. Overfitting occurs when a model is trained with too much information that it starts to learn the noise in the data. The trained model usually ends up performing more accurately on the trained data but less accurately on test (unseen) data. It is important that the model generalizes well to unseen data. Learners might just focus on training a model with the highest accuracy possible. (Note: I'm not trying to introduce new concepts; but overfitting/underfitting is something students will experience naturally when they experiment with different models.)

What learners' thinking about this concept looks like (from your own experience or from research sources that describe challenges and misconceptions around this concept).

A. When students have an incomplete understanding, or don't understand, they say or show:	B. When students understand, they say or show
- Not sure how to start the tree / no plan to pick a root node. - Not sure what the data looks like after picking a root node. - Not sure how to continue splitting the data to grow the tree. - Not sure what the metric is used to decide on the split. - Not maximizing accuracy - the model underfits or overfits	- How to pick the root node of the tree. - What the data looks like after picking the root node. - Description of the metric used (e.g., accuracy) to determine the best split. - How to continue to grow the tree. - Maximizes accuracy - the model performs "just right" (not overfitting or underfitting)

What are some examples of tasks that make learners grapple with your concept, and make their thinking visible so that you can distinguish between A and B, above?

Some phenomena learners might have to explain:

When they play with a toy dataset and try to come up with a decision tree by hand: How each step in their construction of a decision tree model maximizes the prediction accuracy?
When they are on the computer and use a ML package: How well does the trained model perform on trained and new data? Does it overfit or underfit? Why is it "just right"?

Something learners might have to design (including an experiment or a process):
Most learners will iterate through datasets a few times before coming up with a working decision tree model by hand. Once they start working on the computer and using machine learning

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libraries, they will need to come up with a model that maximizes the accuracy and minimizes overfitting.

Which direction(s) seems most promising to you? Draft a learning outcome and a content prompt.

The content prompt is what the learners will be asked at the end of the inquiry activity to demonstrate what they have learned. The learning outcome is more specific than the "concept" and specifies exactly what you want learners to learn in the activity. Examples of these are available on the participant wiki.

Learning outcome:

Learners will use the concept of a decision tree to analyze and solve a predictive problem by maximizing the prediction accuracy.

Content prompt:

Use your understanding of a decision tree to explain/justify how your model solves a predictive problem and maximizes the prediction accuracy.

[All members]
Revised: **Build a decision tree to accurately predict a desired attribute of a dataset. Explain or justify how your decision tree solves this predictive problem and maximizes the prediction accuracy.**

Demonstrate that your decision tree maximises accuracy by plotting something?

How do you feel about your prediction? (This might open a doorway for them to reflect on when using a decision tree is a good idea or a bad idea, gateway to other ML options)

For First Team Meeting (before Inquiry Institute)

What teams should generate during the first team meeting working time:

Breakdown the content into discrete knowledge statements that together make up the concept:

Toy problem - simple dataset and students try to come up with a decision tree by hand. This helps them understand the underlying algo before they use the computer.

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Real-world problem - a real-world dataset (larger than toy problem) where students will use a computer and machine learning package to create decision tree model and perform analysis. Introduce the concept of splitting data into training and testing sets.

Dimensions of Content	A. When students have an **incomplete** understanding, or don't understand, they say or show:	B. When students **understand**, they say or show:
[Toy problem and real-world problem] What are you trying to predict? Predicting an attribute of the dataset	Can't describe what the input or output of the model.	Can describe what the input and output of the model is.
[Toy problem] How did you pick the root node? The root node is the most informative attribute in the dataset for the prediction	- They don't know what root node means - They don't have a root node. - Picked a node but didn't check how it maximizes the accuracy (or information gain?).	- They have a root node. - They have a root node and it maximizes the accuracy (or information gain?).
[Toy problem] How did you iterate through the data and continue growing the tree? Each node/level is chosen such that it continues to maximize information gain	They can't describe a procedure (mentally or writing down) to select features to split the nodes and continue growing the tree. Didn't compare all features, going with intuition or just a couple, didn't calculate accuracy just pick randomly	They can describe a procedure (mentally or writing it down) that they use to iterate through features. One feature at a time, pick feature, test how accuracy changes, check accuracy of each feature choice, compare all features, split on feature that gives highest accuracy, analyzed features
[real-world problem] How did you decide on the final tree? What is the size of the tree (number of nodes and	- Tree is too small or too big - not thinking about best accuracy. - Model is underfit or overfit.	- They know when to stop growing the tree - pick the simplest tree while retaining the best accuracy

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levels)? When did you stop growing the tree?	Don't know how to plot complexity of the tree vs. accuracy. - Has the plot but can't figure out which tree is the best. - Has the plot but pick the wrong tree.	- Model is "just right" - doesn't underfit or overfit. - Show a plot of the complexity of the tree vs. accuracy and pick the correct tree to use.
[Toy problem and real-world problem] How did you calculate the accuracy of your model?	- Doesn't know how to calculate. - Calculated incorrectly (didn't get number of correct examples or not understanding what is accuracy)	Shows number of correct examples divided by number of all examples. (or something similar to this)
[Toy problem and real-world problem] What is your final accuracy of the trained data?	Not knowing how to calculate by hand (toy problem) or use the provided code (real-world problem).	Calculated by hand or use provided code.

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Inquiry Institute

Inquiry Institute General sessions Days 1 - 3

This space can be used to take notes about any sessions or ideas from the beginning of the Inquiry Institute.

- Comparing Approaches / 3 Kinds
- How Learning Works
- Light & Shadow or Analog 2 Digital Inquiry experience and reflection
- Leadership & teamwork

Notes:
Practice and feedback: design activities so that students get a chance to incorporate our feedbacks. Maybe we can do some of these?

1. Demo simple example of how decision tree works (as a group), then let students build decision tree with a toy problem in their own groups.
2. Demo some code on how to ingest data with a library using simple data, then let students play with a real world data.
3. Building a decision tree by nature is an iterative process, so for example, if they don't understand how to pick a node, we can point things out and they should be able to incorporate our feedback and correct their tree.

[All members]
During synthesis, talk about how decision tree is only one algorithm in this ML library. There are many more algorithms that students can try. And when you look at a different algorithm, read about how it works and the parameters that you can adjust to get the best model. Don't just blindly use the method or use "default" parameters. [LA would be AWESOME at presenting this because she is quite passionate about it.]

Equity and Inclusion Design Approach: Day 1

Your design team will develop an approach to the activity design that intentionally supports equitable and inclusive learning, and considers learners from marginalized backgrounds.

Use the space below to outline:

- Your big-picture E&I aspirations--ideas that can influence your thinking
- Initial Draft of your team's E&I design approach. The ISEE E&I Reading outlines Focus Areas and strategies derived from those Focus Areas that are a useful way to organize or frame your early ideas
    - What specific idea(s) (such as identity or mindset) are influencing your approach, at this point?

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- How might those ideas influence your approach to the activity design?
- What kinds of strategies might you design in to address those ideas?

[All team members]
Questions to ask Austin

- What projects will the interns be working on? Are they expected to know how to code? No, there will be many different backgrounds from CS majors to those who haven't interacted with a command line before
- How long do we have the students each day? Austin will send us a timeline from last year
- Can everyone afford a laptop? Yes, expected to have them for other parts of internship (remember they will have all the kinds of operating systems, and possibly outdated)

E&I focus areas

- **Developing an identity as a person in STEM**
  - Acknowledge students' work; try not to patronize students
- **Learners' goals, interests, and values**
  - Datasets related to Hawaii (renewable energy, astronomy, etc.)
  - Find out specific skills students need to have for internships and try to incorporate some of them in our activities
  - Students with different backgrounds: Pair students who know how to program with those who don't know how to program

Equity and Inclusion Design Approach: Day 3

After wrapping up the E&I session on Day 3, use this space to capture:

- Revision of your teams E&I Design Approach. Refine your draft/initial ideas, above from Day 1, based on:
  - Your experience with inquiry and learning about inquiry components that should be part of your design as well
  - The discussions in this session. Have any new thoughts or ideas come up that could inform your team's approach?
  - How your team thinks your approach is connected to, or derived from, a specific idea (such as identity or mindset) from the Focus Areas.

[All members]
E&I focus areas

- **Developing an identity as a person in STEM**
  - Acknowledge students' work; try not to patronize students
- **Learners' goals, interests, and values**

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        - Datasets related to Hawaii (renewable energy, astronomy, etc.)
        - Find out specific skills students need to have for internships and try to incorporate some of them in our activities
        - Students with different backgrounds: Pair students who know how to program with those who don't know how to program

- E&I: Students' interests; ownership; identity
    - Different datasets or same dataset with different questions to ask/answer
    - Toy problem - same dataset for all students so they can check their work with each other
        - Hawaiian themed?

- E&I: Beliefs and biases about learning, achievement, and teaching
    - During introduction mention that ML is not just for CS; it's applicable to many different disciplines.
- E&I: Multiple ways to productively participate
    - We will mix CS and non-CS folks
- Stereotypes?

Assessment-Driven Design

Space for notes:

[All members]

Also see content rubric above.

LA's drawing during our discussion:

This is a plot we want students to draw when they experiment with real data and a decision tree library. And hopefully students will pick the model with highest test accuracy and least complex.

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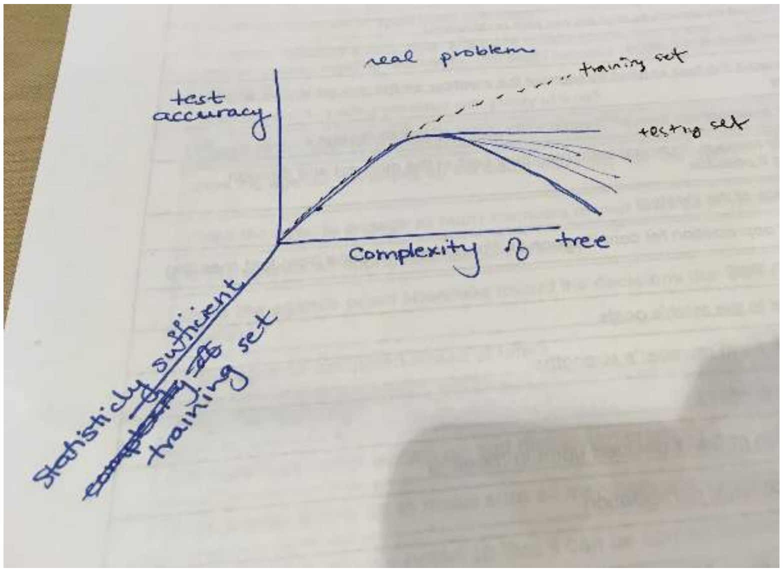

Recall backward designs:

Define learning outcomes

Define evidence of understanding

Design prompt to elicit evidence

Design activities components

Designing Inquiry Investigations Design Tool

Start with ideas for contexts proposed by your DTL in the initial content proposal (click here to return to that).

- Brainstorm a couple ideas for investigations that your learners might take in developing a deeper understanding of your content goal (as laid out in your current rubric).

Before the Design Institute, spend 1 to 2 hours on your own to sketch out possible investigation paths for your learners. Consider not just paths that you yourself might take, but plausible paths of students very unlike you.

Segments of investigation:

1. Toy problem -> develop tree and calculate accuracy.

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2. Toy problem + concept of train/test set -> After introducing the concept of splitting dataset into train/test set, give students another toy problem -> develop tree and calculate accuracy for train/test set separately.
3. Real world problem + decision tree library -> use library to come up with trees and produce tradeoff plots (tree complexity vs. accuracy) to pick the best model.
4. Test model on data without labels and ask students to reflect on the results -> does it make sense to them?

Very hand holding intro and toy problem to be very supportive for learning what a decision tree is, but allow them to be more inquisitive for optimization

Culminating Assessment Task Design Tool

The content prompt is a key component of the CAT, as that is what elicits the information needed to assess learners through an artifact.
In addition, the CAT may lay out a structure for how students will present evidence of their learning, i.e. what medium they will use to communicate, and whom they will be communicating to, and what the instructors will be doing. Common CATs are poster presentations or jigsaw discussions, but these are not the only formats that could be used.

- What are some formats (e.g. jigsaw, posters, etc) students could share their understandings during a culminating assessment task? (Optional: List the strengths/weaknesses of these ways of sharing. E&I considerations are one dimension for pros/cons.)

[all members]
Jigsaw (we will probably do this)
- pro
    - informal discussion format;
    - need to understand everything, and not just what you did
- con
    - need to make sure there's enough differences in questions so that when teams split to 3 facilitators there's no overlapping of questions
- Note: we need 3-person teams

poster
- pro - sharing results in front of audience
- con - anxiety of sharing in front of audience takes away from learning

- How could your CAT mirror authentic STEM?

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- Does your content prompt explicitly ask for learners to refer to evidence as they explain their findings? If not, does your CAT need supplemental prompt(s)?
- What kind of artifact could your CAT have learners produce, so that you have something to assess with your rubric? Does your content prompt elicit that artifact, and if not, what additional instructions should the CAT give learners?
- (As you narrow down from the brainstormed possibilities): What is the format of your culminating assessment task?
- Will learners have an opportunity to demonstrate their individual understanding?
- Learners with different backgrounds may engage differently in the culminating assessment task. How will you make sure all your learners' contributions are recognized? How does your culminating assessment task engage all learners?

Scaffolding Practices Design Tool

This tool will help you think about how you might help your learners improve at a core STEM practice, rather than just doing the practice. It can help you think about adding and/or refining activity components to better support your learners' improvement at a practice.

This tool can be used at various points in the design of your activity, too. Early on, use the first few questions to help you identify the dimensions of your core STEM practice that may need scaffolding. The later questions in this tool can be used when you are fairly far into the design process, after you have already defined your main practice and content goals and drafted up a few of your activity components.

Questions to consider early on in your design process (e.g. at Inquiry Institute):

- What is nuanced or challenging about this core practice (or a dimension of the practice)?
- What would various levels of experience with (or mastery of) the practice look like?
- Would students have choice and challenge with this core STEM practice (compared to other STEM practices)?

Questions to consider once you are a bit further in the design process (e.g. Design Institute):

- What level of experience and skill with this practice might your learners bring to the activity? How would you find out more about their skill level early in the activity?
- Will there be opportunities to give learners feedback and an opportunity to try the practice again?
- At what points during an inquiry activity might learners be able to engage in dimensions of the practice?
- What kind of support/scaffolding, for this practice, can you provide for your learners?

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Practice Proposal Design Tool

Each participants is expected to generate a proposal for the STEM practice that will be the focus of their team's inquiry activity. Work on this proposal is intended to give design teams time to think about STEM practices appropriate for their teaching venue and their content area and to give their team a jump start on picking a practice goal.

All team members are expected to post their "practice proposal" on here in the Design Notebook at least 3 days before the Design Institute so that their teammates can look at them in advance of the Institute. The proposal should include the following:

- **The proposed core STEM reasoning practice that you are focusing on for your activity** (e.g., Explaining results based on evidence, defining problems, designing and carrying out investigations). Consider the needs of your venue and your content goal. Be sure to consult ISEE's "recommended list" of practices.
- **Dimensions of the practice that are most important to focus on in your inquiry.** (e.g., Core Practice: designing and carrying out investigations --- Dimensions: planning controls or defining control samples, identifying shortcomings in the experimental design)
- **Importance of the practice.** Some things to consider: How it might be used broadly in science or engineering, particularly in the field that your inquiry is in; how mastery of this practice might contribute to a learner's development of identity as a scientist/engineer. Is the practice authentic as opposed to simple?
- **The need that supports your choice of this practice** (refer to research, direct teaching experience, or assessment results that indicate this practice is challenging for learners). See the following wiki page for a list of recommended practices and references: http://inquirydesign.pbworks.com/w/page/105211872/Recommended%20List%20of%20STEM%20Practices
- **Some difficulties learners may have in understanding this practice** (what is known, from above, about the specific challenges, misconceptions, or counter-intuitive aspects of this practice)

Please note that the proposal should be brief (less than 300 words in total) and does not need to be comprehensive. Teams will work more on this at the Design Institute, so just one or two difficulties is ideal. You are not limited to one proposed practice.

For an example of a Practice Proposal, see the ISEE PDP Resources on the participant wiki.

Practice Proposal #1:
Proposed core practice: Using models to develop explanations

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Aspects of practice: Articulate which aspects of a phenomenon are important to include in a model, identifies the relationship between inputs and outputs, and model components, and recognizing limitations of a model.
Importance of practice: The practice is central to research scientists and engineers who rely on building models to help them solve problems and explain results.
Supporting STEM identity development:
Building models is an important tool for research scientists and engineers to help them explain certain phenomenons. Strengthening learners' ability to do this practice may help them gain more confidence in solving new problems that require building models.
Need that supports the choice of practice:
Engineers often use models to analyze an existing phenomenon, and since all models are approximations of the actual systems, they must be aware of models' limitations and assumptions [1].

One challenge is the integration of the performance of the practice with underlying meta-knowledge, making assessing reflective practice within and across science content areas difficult [2]. The other challenge is the interaction among different components of the practice. For example, being able to evaluate a model means an understanding of how the model was constructed initially.
Difficulties in understanding or engaging in the practice:
When learners have difficulties with using models to develop explanations, it may mean that they have trouble identifying the relationship between inputs and outputs or articulating important features of the model.
References
[1] Schweingruber, Heidi, Thomas Keller, and Helen Quinn, eds. *A Framework for K-12 Science Education:: Practices, Crosscutting Concepts, and Core Ideas*. National Academies Press, 2012.
[2] Schwarz, Christina V., et al. "Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners." *Journal of Research in Science Teaching* 46.6 (2009): 632-654.

Practice Proposal #2:
Proposed core practice: Designing investigations.
Aspects of practice: To decide which variable/features are important in deciding outcomes; investigate which model is better.
Importance of the practice: Designing the investigations is important to understand the dynamics between dependent and independent variables to explain the proposed hypotheses.
Supporting STEM identity development:
Ability to drill through data and be able to visualize the information content is a first-hand experience of realizing how the richness of data can help answer important questions/make predictions. This opens up numerous possibilities of all the questions that are waiting out there to be answered, based on mathematical principles, and thus strengthen a STEM identity in students.

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Need that supports the choice of practice:
Given the nature of Machine Learning, it is essential to determine which feature/variable are important factors to determine outcomes.
Difficulties in understanding or engaging in the practice:
Deciding the choice of metrics: accuracy/information gain?Choosing the right algorithm.

Practice Proposal #3:
Proposed Core Practice: Using models to develop explanations
Dimensions of the practice that are most important to focus on in your inquiry: (1) Articulating which aspects of prediction are important to include in a decision tree, (2) Distinguish between a prediction from the decision tree and a sample where we know the truth, (3) Recognizing limitations of a decision tree to predict a label of the data and how that might affect the situations where it is optimal/beneficial to use, (4) Adjusting the decision tree to incorporate new/different data, (5) Selecting nodes in the decision tree that are most relevant to split the data on to maximize prediction accuracy, (6) setting up a training set and a test set, (7) planning procedures that will allow the most accurate predictions to be made with a decision tree, (8) testing the accuracy of their decision tree

Importance of the practice: Machine learning is becoming highly used in data analysis in most STEM fields. Being able to dissect one implementation of machine learning as a model to predict data will allow students to be more comfortable exploring other machine learning options, and getting a sense of the 'black box' as well as how to use it. They will gain skills to critically analyze when different machine learning algorithms are good/bad approaches.

The need that supports your choice of this practice:
Something about students understanding correlations in data, but there will always be outliers/noise/uncertainty
Something about students understanding this isn't a physical model that tries to describe some physical phenomena, but is a model of the data itself

Some difficulties learners may have in understanding this practice:
They think there is a 'right' answer
Uncertainty on your prediction?

Design Institute

Working with Goals and Rubrics

For examples of rubrics, see the ISEE PDP Resources on the participant wiki.

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Revised: Build a decision tree to accurately predict a desired attribute of a dataset. Explain or justify how your decision tree solves this predictive problem and maximizes the prediction accuracy.

Content rubric: The template below shows a "binary" rubric in which students are scored for "knowing" (1) or "not knowing" (0). If you prefer to score with a finer gradation, it is fine to add one or more intermediate columns and score on a 0-2 scale (see example below).

Although these examples show three dimensions, you may have more or fewer. Avoid making too many dimensions as that would make it hard to focus on the critical aspects of the content or practice that you are focusing on.

Dimensions: **Components or "knowledge statements"**	**M** **evidence needed to make a judgment is missing**	**0** **evidence that learner has misunderstanding or incomplete understanding**	**1** **evidence that learner has sufficient understanding**	**Score**
[Toy problem and real-world problem] **A decision tree predicts a desired attribute of a dataset.** (What are you trying to predict?)		- Can't describe what the input or output of the model. - Can't describe the attribute trying to predict.	- Can describe what the input and output of the model is. - Can describe the attribute trying to predict.	
[Toy problem] (How did you iterate through the data and continue growing the tree? How did you pick the root node?) **The process of choosing the "best" feature to**		- They can't describe a procedure to select features to split the nodes and continue growing the tree. - Didn't compare all features; going with intuition or just tried a few features randomly	- They can describe a procedure that they use to split the nodes and grow the tree. - Compared all features for splits by calculating resulting accuracies.	

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split the tree on at each level.		- Picked a node but didn't check how it maximizes the accuracy.	- Picked nodes that give highest accuracy.	
[Toy problem and real-world problem] (How did you calculate the accuracy of your model? What is your final accuracy of the trained data?) **A metric to split the tree on is accuracy.**		- Doesn't know how to calculate. - Calculated incorrectly (didn't get number of correct examples or not understanding what is accuracy)	- Shows number of correct examples divided by number of all examples. (or something similar to this) - Calculated by hand or use provided code.	
[real-world problem] (How did you decide on the final tree? What is the size of the tree (number of nodes and levels)? When did you stop growing the tree?) **Tradeoffs between accuracy and complexity of the model.**		- Tree is too simple (underfit) or too complex (overfit) - not thinking about tradeoffs between complexity and accuracy. Don't know how to plot complexity of the tree vs. accuracy. - Has the plot but can't figure out which model is the best. - Has the plot but pick the wrong tree.	- Model is "just right" - doesn't underfit or overfit. - pick the simplest tree while retaining the best accuracy - Shows a plot of the complexity of the tree vs. accuracy and pick the correct tree to use.	

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Practice rubric:

Optimization (talk to Scott)

- Possible practices: optimizing & improving, analyzing trade-offs, breaking the problem down
- Will need to come up with our own dimensions (using tables from the paper as a starting point)
- **Will come back to this later**

Backup practice: Using models to develop explanations

Notes on dimensions of optimizing

1. Deciding on a metric to optimize
2. Identifying which variables are most important / contributing most in the optimization
3. Tradeoffs between metrics and variables in the optimization

2 misunderstanding - During initial exploration, varying multiple variables at once before understanding how the system behaves

Think about optimizing driving

Metric examples: mpg, time to destination, safety

Variables examples: speed, acceleration, route

Dimensions of core practice:	**Lack of evidence** **did not observe learners enough to decide between A and B**	**Evidence of difficulty** **what it looks like when a learner needs to work more on the practice**	**Evidence of proficiency** **what it looks like when a learner is proficient with the practice**
Deciding on a metric to optimize		- Can not describe what makes a model “good”	- Can describe what makes a model “good”
Identifying which variables are most important in the optimization		- Does not identify all variables	- Identifying all relevant variables

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		- Does not identify primary variables, or focusing on too many	- Deciding the primary variable for their investigation
Trade offs between metrics in the optimization		- is not comparing different metrics (e.g., they only look at one)	- compare different metrics and notice how they are related to each other

Focusing on Investigations Design Tool

Start with the ideas you considered in the "Designing Inquiry Investigations" design tool, and the core concept and practice your team has been considering.

- Consider a question or problem one of your learners might investigate, and how they might go about it.

Real world problem + decision tree library -> use library to come up with trees and produce tradeoff plots (tree complexity vs. accuracy) to pick the best model.

    - Is there more than one way to productively "figure it out"?

Learners would experiment with different depth of the tree (complexity of the tree) and record the resulting accuracy of the trees. They would then plot complexity vs. accuracy and pick the model with best accuracy.

One other option for students to try to 'figure it out' is by playing with the proportions of training/test data to maximize the accuracy rather than playing with the complexity of the tree.

    - Will learners use your core concept to figure it out?

Our core concept (decision trees) is very explicitly used in our content prompt, and we will guide them through out the introduction to use a decision tree to accurately predict an attribute of the data.

- Are the resources needed for the Investigations practical and something you are likely to be available? (be sure to consider how a simulation or existing data set might be used)

Their own laptops or computers installed with Python (Jupyter Notebook or Jupyter Lab).

Real world dataset

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- Dataset with missing value - we can give them entire dataset and talk about predicting missing values, or give them portion without missing values first to train on, and then give them the portion with missing values.

- What are some challenges (e.g., misconceptions) learners may have in getting to your main content goal?
    - Students might show up with python not installed or the software package not working
    - Will learners have to grapple with the challenging or subtle aspects of content?
    - Students might not understand why complex models have worse accuracy.
    - Our approach to using decision trees is very data-centric, and the problem to be answered is chosen based on the dataset provided. A misconception that could arise is that students might tend to believe that they can apply decision trees when they only have a dataset, with attribute/feature values provided to them, while in real world applications, the approach is often problem-centric, for which, there are data dumps, on which feature engineering is used to arrive at the data that can directly be used as input to a decision tree.

- Describe how you'll find out what your learners are thinking about as they investigate
    - Facilitators moving around the room and poking/prodding each group about what their decisions are and why they made them
- Describe a facilitation move or scaffold you might use to help learners reach your content goal
    - After the students have time to build a tree and start to calculate accuracy, bring the group back together and show an example of a simple tree having higher accuracy than a much more complex tree
    - Give students time to consider what they want to predict from the data set and as facilitators we can give them guidance for what is possible, what is too hard, too easy etc, but allowing them time to think of the question they want to answer will raise interest
- Of the different STEM practices (or different dimensions of one practice), which will learners use in a way that provides challenge and choice?

[all members]

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Trade-offs between different metrics (complexity of model and accuracy).

- Describe a facilitation move or scaffold you might use to help learners engage in the practice. Will learners have to grapple with the challenging or subtle aspects of the practice?

Push them to keep exploring metrics (how does an increase in complexity of model affects accuracy).

- How might learners in these investigations end up answering your content prompt? What might their ultimate artifact(s) look like? This is a good double-check that your CAT, rubric, and investigations are aligned.

Trade-off plots.

Equity and Inclusion Design Approach

Taking into consideration the E&I paper that you read, the papers you heard presented, and the papers that your Design Team members read, revise your team's E&I Design Approach to address the following:

- How does your approach consider learners from marginalized backgrounds?
- Can you connect your approach to more subtle aspects of the idea that your idea is based on?

As your team moves closer to determining how you will design for E&I in your activity, be sure to transfer these ideas into the E&I Design Approach header in your Teaching Plan.

[All members]

- Multiple real-world datasets to address different STEM identities (science, altruistic, disruptive).
- Encourage collaborations - jigsaw, teamwork.
- Every student will get to work on their laptop, but they need to discuss things and consolidate results as a group.
- **Context the design to let students know that there will be iterations. Give feedbacks at various iterations. (growth mindset)**
- **Talk to students about the lack of proper background is ok. (address learners from marginalized backgrounds). Acknowledge students' background.**
- Dataset that includes weather, oceans, surf, astro observing abilities, (engineering/CS focused)

E&I in Facilitation

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Individually, you might have some ideas about how you would like to consider facilitation (the in-the-moment interactions with individuals or groups of students) from an E&I standpoint. As a reminder, the 3 purposes of facilitation are:

1. Finding out what learners are thinking
2. Helping learners progress towards learning goals, with respect for learners' paths.
3. Attending to social interactions

Record notes on a specific idea from a specific E&I theme focus area (can be the same as your team design approach, but doesn't have to be) that you would like to incorporate into your own facilitation. Compare these ideas to less productive instructor-student interactions.

- Space for notes
-

Make sure students with non-programming backgrounds are also getting the code to run and not being observers. Emphasize that the code is going to be used just as a tool, and doesn't require particular skill. (Inclusion)
Nudge them in a direction where they get to see for themselves how accuracy starts to drop, even with more complex trees.
Make sure the students in a team interact and discuss, instead of just investigating on their own. Ask them questions at each point as a team: what is the best accuracy they have, and how they feel about it as a team (good enough/not good), whether to stop?

Mindful of not being patronizing, encouraging a growth mindset (think more about good wording for this, sounds like Scott has a lot of good ones), patience when asking questions and not giving the answers, encouraging peer teaching/learning, maintain an awareness that not everyone has the same goals/identity as me

- Check up on teams often and make sure to give enough time for all teams.
- Address teams as a group rather than individual person.
- If we address individuals make sure to talk to everyone on the team.
- Ask teams about
    - what they are working on right now
    - how did they get there
    - what they plan to do next
    - are they stuck on anything
- If teams are stuck, praise effort and provide hints on how to proceed rather than just giving answers.
- Encourage teams to help each other (context at the beginning of the activity and throughout).

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- If we see teams with dominating person, make sure to address the non-dominating person when checking up on teams.

Ideas for things to do before starting the raising questions portion:

Show example (from another example data set) of a prediction from a decision tree and ask which feature is more informative for this prediction, then show them the answer. This will generate questions around which features are most informative for a prediction.

Present the toy dataset features (not many features), brainstorm on what they want to predict, what are the most informative features, then go straight into working with the toy dataset

With toy data set, visualize numbers on screen, highlight rows and draw decision tree on board

Raising Questions Design Tool

- What are some kinds of the kinds of questions that you want your learner to pursue in their investigations?

Is feature X,Y,Z informative of feature A,B,C?
Is feature 1,2,3 not informative of feature 7,8,9?

What we don't want them to ask: want the questions to be more predictive driven rather than content driven
Which algorithm is best to use to make a prediction?
How does a decision tree work?
What is a feature?
What is a root node?

If you don't know specific questions that learners will investigate, then it is too soon to work on this component.

If you have identified specific questions you know you want learners to ask, proceed:

- What puzzling or surprising observations might lead learners to ask those kinds of questions?

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    - Consider “why” questions that may lead to investigations that are more scientific in nature
    - Consider “how” questions, or “how would one go about..,” or “what is the best way to…” that may lead to engineering investigations, investigations involving computing control structures, or statistics knowledge

  We will show actual examples and highlight patterns that will help predict a label/target.

- How can the Raising Questions component allow for different sorts of questions from learners with different levels of prior identification with science/engineering?

The dataset/features will be something familiar to everyone regardless of their background.

- What puzzling or surprising observations might lead learners to ask those questions?

[same question as above?] We will show actual examples and highlight patterns that will help predict a label/target.

- How will your Raising Questions component enable you to find out about your learners’ prior knowledge / experience with the content goal?

More sophisticated data analysis response - letting the data inform your decision.

People without data analysis background might be more adamant about what features inform the prediction, based on prior belief.

- What will your learners be doing/saying during the Raising Questions component? What will the facilitators be doing/saying?

We will split the students into 3 groups (3 facilitators) so there will be more interaction with students. Every student will get a chance to provide input in a smaller group setting.

In your Teaching Plan, each facilitator should have an individualized plan for what they will say and do during Raising Questions.

Maybe give suggestions for correlations in the data to elicit them to start thinking about prediction like questions rather than content like questions

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Designing Synthesis/Reflection on Practices Design Tool

- What main points related to your content goal will you review in your synthesis?
  - How will you connect your learners' work to your main content goal?
  - How will you acknowledge each team's or individual's contributions to the larger group's collective knowledge?

[all members]

Talk about different prediction problems teams have worked on (mention the teams).

- Depending on the target, some teams might have lower prediction accuracy than others (nature of the data)

Talk about teams' results - best model and new prediction reflection

- their accuracy, final tree, did they see overfitting, tradeoff plots
- Prediction on new data - teams' reflection may be different (some are surprised by the results, some are not)
  - Teams with low prediction accuracy **should** question the new prediction

Other types of problems/context they would like to apply decision tree learning to.

Decision tree learning is only one type of machine learning. **But you can use the same practice (optimizing the model) for any other types of algorithm (reflect on the practice).**

- Show them different algorithm in sklearn
- Code to call them (very similar syntax) (e.g., SVM, naive bayes)
- Show them the documentation so they can learn more about different algorithms

You can apply this to any problem you come up with in the future.

Show some cool examples of ML (state of the art).

- How will you help your learners reflect on the fact that your content goal has broad explanatory power? (beyond the phenomena or problems they investigated)
- How will you convey respect for the different ways learners explained during the CAT?
- How will you engage your learners in reflecting on the main practice goal?
  - What prompt(s) will you give them to help them think about how they engaged in the practice in a way that is disentangled from the content, so that learners will gain an understanding of the generalizable aspects of the practice (from your rubric)?
  - How will you help your learners reflect on how your main practice goal applies to many contexts? (beyond the phenomena or problems they investigated)

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Introducing the Activity

Who will introduce the activity?:

List key points for contexting your inquiry activity:

- How will you convey that this activity is different from other activities your learners may have experienced?
  - Let them know that this is not a lecture. There will be a lot of self hands-on learning.
  - Facilitators guiding them all along,but make them think on their own, ask questions.
- What expectations do you have for your learners that you will make explicit in your Introduction?
  - Work in groups,everyone contributes and take responsibility of their teams
  - coding experience NOT required.
- How will you convey that this activity mirrors authentic research or engineering design?
  - talk about examples from software industry, emphasize we will work with a real world problem.
  - Might mention in introduction and/or after raising questions:
  - Investigating is a creative process and you are likely to hit some difficulties as well as breakthroughs, these difficulties are a normal part of the process, and understanding that they are a normal part of the process will prepare you if you hit some rough patches.
  - If you get stuck: talk to facilitator, check in with other groups, reflect on experience (oral/written), take a break/distance
  - Getting stuck can be frustrating, it can also be exciting, on the verge of learning something new. Feel you 'should' know how something works and doesn't work that way, give up OR change the way you think about it. Getting stuck in a natural part of the process, not doing anything wrong, on the other side can be the joy of having learned something new
- How will you convey the role of the instructors?
  - Facilitators will guide you if you are stuck, but we are not here to just give you answers.

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Describe any background content or information about practices you will want to share with students before the activity begins.

Show example ML predictions (cool/fun/hip), get them interested in prediction, which features they might want to predict, start showing correlations in data, use some features to predict others, will naturally want to be “most correct” (won’t introduce accuracy until later)

When do we want to introduce validation and a training/testing set? Maybe same time as accuracy? Context of toy problem or real world? We’ll have to tell them, they won’t discover these things. Maybe after starting on the real world problem and getting an initial prediction? Then they’ll have gotten over the hurdle of getting the software to run.

Contexting Design Tool

Consider the following (in relation to each component of your activity):

- What do you want learners to do in the upcoming component (especially that might be different than what they are used to)?
- What is the objective of this component you are contexting, and how will you convey that to the learners?
- How might they go astray or diverge from what you expect of them?
- How can you help them see that what they are about to do is authentic to science or engineering?
- Is there anything from the prior activity component that needs contexting?
- What is the role of the instructors, and how will you convey that?

How are you using contexting to convey high expectations for all and project an inclusive view of STEM achievement?

Designing Thinking Tools Design Tool (if applicable)

Consider your main content goal for this activity.

- What level of experience with this content might your learners bring to the activity?
- How will learners apply the content as they engage in investigations?

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- How will you find out what learners are thinking as you facilitate them, related to the main content goal?
- What are some challenges learners may have in getting to your content goal? How will you facilitate learners through those challenges?
- Are there any “leaps” in understanding learners might have to take in order to reach the goal? If so, this might be a good place to design in a thinking tool.
- Are there any demonstrations or short activities your learners could engage in, that could help learners make a necessary leap in understanding?
- If you choose to design a thinking tool, consider whether it would be best presented in a plenary way (to all learners at once), or whether it would be better to have facilitators present the thinking tool to individual investigation teams if/when the teams need it.

Rest of the Design Institute:
- Practice
- Draft prompt for the overall task to be completed during investigations
- Final practice reflection prompt
- Introduction

Week ending:
April 21 - investigation; explore/decide on datasets
April 28 - investigation; explore/decide on datasets
May 5 - investigation; decide on dataset
May 12 - buffer time
May 19 - Teaching plan ready for review
May 26 - Finalize teaching plan, slides, code
June 2 - Finalize teaching plan, slides, code
June 9 - Finalize teaching plan, slides, code
June 15 - Fly to Hawaii

Check in at each meeting how much time people have spent time working on things.
Use effective meeting sheet as a checkoff list.

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