Lesson Plan: Mendelian Genetics

Context: This is a lesson plan for a course on fundamental genetics. The students are sophomores through seniors who are biology majors and have taken prerequisite courses that cover this material briefly. In terms of the course setup, this lesson comes after review about meiosis and mitosis and before expanding on mendelian genetics with more complicated inheritance patterns than complete dominance. There are 150-200 students in the lecture section. The course currently meets in a lecture hall with stadium style seating but there is a classroom with all moveable desks that makes group work available that the course is taught in some semesters.

Relevant course objective: Student should be able to construct a model of meiosis and use the model to explain Mendelian Inheritance

Lesson Objectives:

1. Students should be able to describe Mendel's Law of Segregation and Law of Independent Assortment
2. Students should be able to use a Punnett Square and a branching diagram to determine offspring genotypes and translate genotypes into phenotypes for complete dominance inheritance
3. Students should be able to diagram a monohybrid cross, dihybrid cross, test cross, and reciprocal cross and explain when each cross might be done.

Activities:

Pre-Lesson Assignments:

1. Read selected few textbook pages on Mendelian Genetics, including reference to helpful images
2. Watch video lecture on Mendel's crosses (about 7 minutes)
    a. Includes Punnett squares and branching diagrams
    b. Introduce different types of crosses (testcross, reciprocal)
        i. Reciprocal will be more important when X-linked traits are discussed in the follow lesson period
3. Watch video lecture on Mendel's laws (about 7 minutes)
4. Weekly problem set available to students, not due until after the lecture and a recitation section focused on helping students complete the problem set

Lesson Plan:

1. General outline of the class period: start class with a clicker question about today's topic addressing a potential misconception about the topic, then move into a 5 minute review lecture, and spend the rest of class working through drawing models and peer learning clicker questions that are answered individually, then in groups, and then going over the answer together. If there is still confusion after the first round of group work, there will be some hints given and a second round of group work to answer the question.
2. Misconception to address at the start of class:

a. Students may still have misconceptions about meiosis from prior classes and from the review the previous week. The initial question would ask: Which of these are the products of meiosis from this parent cell? The answer options should a parent cell with 6 chromosomes (n=3) would be images of cells that are either the product of mitosis or meiosis including options. Follow up questions would ask students more about the options presented and how we get each one (independent assortment, recombination, segregation)
    i. Note: I don't think this question is super great yet, but this is the type of question I'd like to start with to warm up students and get them thinking about what we learned last time and how it will apply to the material for today while potentially addressing some misconceptions.
b. Then move into a review of a few slides focused on independent assortment, recombination, and segregation.
    i. Include explicit slides that students are not expected to be able to solve all the problems before they walked in the door today. The activities in lecture are designed to provide students practice and feedback to give them the tools and knowledge to solve these types of problems and similar problems.
c. Q and A: how are we feeling about this material? What questions and concerns do you have right now?
    i. Students can answer out loud, or send messages to TAs that TAs will share without sharing the student's name during class or TAs can answer the questions after class if students don't come up with questions during the lecture time.
d. Another clicker questions could include asking about meiosis output with and without crossing over
    i. Potential prior knowledge/misconception: students may be aware of crossing over as recombination, and think that if it is possible for recombination to occur, that it always occurs for each allele.
e. Then we would transition to connecting genotypes to phenotypes. Talking about 2 allele systems with complete dominance.
f. Clicker question: A mouse with the genotype AA and black fur is crossed with a another mouse with black fur and the genotype Aa. What are the potential genotypes and phenotypes of their offspring?
g. Then make it more complicated with a monohybrid cross
h. Include a question where instead of alleles represented by letters such as 'A' and 'a', alleles are represented as "AGGTCTT" and "CGGTGAA" to emphasize that alleles are DNA sequences.
i. Then a dihybrid cross
    i. Show how to solve with a Punnett square or a branching diagram, both are presented in pre-class material so student groups may discuss both ways as solutions

j. And finish class with a problem where students are given F2 phenotype ratios, and they need to figure out F2 genotypes ratios and the genotypes of the parents
k. NOTES:
    i. clicker questions not gotten to in class can be used in recitation sections or to start lecture the following class period.
    ii. I would like to use real world examples of complete dominance if possible. Most questions I have seen so far for teaching these concepts use made up traits or even mythical creatures (breeding unicorns or dragons). By using research when possible, I hope students will see how this material is applicable to many different systems and so can be applicable knowledge for careers in medicine or ecology.
    iii. Make sure to emphasize the 'why' of each step in problem solving. The goal is not to teach students just how to solve a crossing problem, but for students to recognize why each step is needed to solve the problem. From my limited experience so far, teaching these concepts can just become teaching students to plug and chug on crossing problems while losing the connection to the broader concepts.

Post Lesson Assignments:

1. Complete the problem set (10 questions, unlimited attempts)
2. Online quiz style homework (fill in the blank, multiple choice) of 10 questions where students get 2 attempts on each question
3. Potential other assignment: draw a concept map that connects the material from last week on mitosis and meiosis with Mendel's laws and inheritance of completely dominant traits and one other topic of your choosing from Unit 1 (molecular genetics unit).
4. The outcome of these assignments will be identified at the end of the week to see how students are doing to meet course objectives and instruction can be tailored in the next few classes to emphasize/get at in a new way objectives that students seem to be still struggling with.

Assessments:

a. Responses to clicker questions provide an immediate assessment in progress towards meeting objectives
b. Ask student to model a parent cell, the cell in anaphase I, the cells in anaphase II, and the daughter gametes. Then use this model to explain Mendel's laws of inheritance.
c. You have a pigeon with blue feathers and you'd like to figure out their genotype and if blue feathers are dominant or recessive to gray feathers. Identify the steps you might take below and describe why.
    i. ______ Cross the blue pigeon to another blue pigeon
    ii. ______ Cross the blue pigeon to a gray pigeon
    iii. ______ Cross the blue pigeon to a homozygous recessive pigeon

iv. ______ Mark the blue pigeon and let it mate on its own with multiple other pigeons, follow the phenotypic ratios of the offspring from all mating events

v. ______ You cannot figure it out without more information.

Please explain your response.

d. Typical assessments for this unit include providing students with F2 ratios and asking them to identify the mode of inheritance or multiple choice questions that ask what stage of meiosis recombination and the law of independent assortment are relevant

Reflection

Q1: Objectives – How have you followed recommended practices in identifying your learning objectives? In particular, have you expressed your goals in terms of what students will achieve or be able to do? Are your goals well-defined and measurable? Are they at appropriate levels of Bloom's taxonomy?

The learning objectives presented here are appropriate to start addressing in a single lesson though they will be built on in following class sessions. Each objective uses verbs from Blooms taxonomy and the objectives cover different levels of Bloom's taxonomy. Two of the objectives are at higher levels of Bloom's taxonomy because this lesson is information that will be built on, and it is imperative that students have a strong foundation of knowledge here before we add to it with more complex patterns of inheritance and following more than 2 alleles or more than 2 traits at once. I think each goal is specific about what students will need to do and can be measured through an assessment.

Q2: Misconceptions – What potential student misconceptions have you identified in your lesson plan? How have you planned to surface and respond to these misconceptions?

One misconception I identified was that students may think that dominant alleles for multiple genes are always inherited together or that if crossing over occurs, it occurs at all possible loci. I will address these misconceptions with clicker questions that ask about the potential gametes made from a starting individual that I provide with and without independent assortment, and with and without crossing over. I will also try to provide students with a knowledge framework to organize information by being explicit about the connection between the events of meiosis, Mendel's laws, and why we can use a Punnett square to model crosses. Prior in the course we will have covered DNA replication, transcription, and translation. I also want to be sure to emphasize to students that alleles are different versions of genes, and so alleles are DNA sequences. This will also be addressed as a clicker question and may come back as an end of the unit/final exam assessment where students are asked to follow two alleles for the same gene that make slightly different proteins. The students would be given genotypes of both individuals and sequences of the alleles. Students would then be asked to identify what a blot from each parent would look like, and potential genotypes and blots of the offspring.

Q3: Practice & Feedback – What opportunities for students to have meaningful practice and feedback have you planned for this lesson? What kinds of feedback would you expect students to receive and from whom?

Students would receive peer feedback by working through clicker questions in groups. They would also receive instructor feedback as the instructor and TAs will be walking around to answer group questions and the instructor will go over the clicker question answers as a full section.
From the assignments, students will receive immediate feedback on if their answer is correct or incorrect from the quiz type set up, and then will have recitation sections and office hours to ask questions or receive more information about why their answer was correct or incorrect.

Q4: Sequencing – Why have you sequenced the learning activities you describe in your lesson plan in the order you have planned them?

I have put the activities in this order so that first student prior knowledge can be activated about what we have already learned that is relevant to today. Then, because I know that now all students will have prepared for class, I want to give a short lecture on the material so all students will have been briefly introduced to the relevant concepts before moving into the group work. Finally, the potential clicker question topics I outlined are designed to build on each other so they start as more simple questions that students have likely seen in similar scenarios from perquisite courses and then move to more complex questions

Q5: Alignment – What are 2 or 3 ways your objectives, assessments, and activities are in alignment? Be specific about connections you have planned among these three components.

I have not outlined all potential assessments or really specific details about my activities, but the pre-lesson assignments are design to introduce students to terminology that is relevant in the learning objectives such as the different types of crosses, Mendel's laws, and the tools of a Punnett square and a branching diagram. This same material is then applied to answering clicker questions throughout the lecture with opportunities for students to ask questions in front of the whole class or during groups discussion time on the clicker questions if a student does not want to raise their hand in front of everyone. The post lesson assignment will be variations on the types of question we worked through in class, but also pushing students to apply the knowledge in different scenarios, so asking specifically about using a branching diagram to identify F2 genotypic and phenotypic ratios for a trihybrid cross or asking students to model what the products of meiosis might look like with and without Mendel's laws. Finally, the relevant full course objective is asking students to construct a model, so an assessment would ask students to draw out a model of meiosis and use it to explain Mendelian inheritance. While this assessment is mostly a reframing of the course objective, it could be written so that students are given a genotype for an individual and asked to draw the gametes this individual could make and explain why those are the potential gamete combinations. Questions asking students what crosses they would need to do to answer a question also test if students understand why they might want to know this information rather than students memorizing the definitions of each type of cross. Finally, questions that provide F2 ratios rely on student's ability to use Punnett squares and branching diagrams to work backwards towards the parents without explicitly asking student's to use one of the methods so students are able to apply their knowledge and use the method that works best for them.

Q6: Evidence-Based Practices – How has research on STEM teaching and learning, including but not limited to studies mentioned in this course, informed the teaching choices you made as you planned your lesson?

My lesson plan was really influenced by the importance of providing students feedback to allow them to revise and try again. I particularly like the idea of peer assisted learning as a way of engaging students in active learning through discussions of course material as well as allowing students to get feedback from their peers throughout the lecture and from the instructor as well though the instructor is likely unable to provide individualized feedback to every group. This topic is one that students likely have prior knowledge on, so I would like to be able to address student misconceptions and provide students with a knowledge structure that allows them to connect mendelian genetics, something they have likely covered before, with topics covered earlier in this course such as DNA replication, transcription, translation, transformation, or blotting techniques.

The influence of the growth mindset also influenced how my lesson was designed. I recently read a paper (Bauer et al. 2020) that discussed how the growth mindset in addition to active learning increased assessment scores for students from all demographic groups while active learning on it's own increased scored of white students when compared to a traditional lecture but actually decreased test scores of Hispanic students compared to a traditional lecture. Incorporating elements of teaching students about a growth mindset into each lesson can help with the affective domain as well.

Reference

Bauer, Angela C., Vernon M. Coffield, Dinene Crater, Todd Lyda, Verónica A. Segarra, Kevin Suh, Cynthia C. Vigueira, and Patrick A. Vigueira. "Fostering Equitable Outcomes in Introductory Biology Courses through Use of a Dual Domain Pedagogy." *CBE—Life Sciences Education* 19, no. 1 (March 2020): ar4. https://doi.org/10.1187/cbe.19-07-0134.