Benchling

Adapting Lab Courses for Virtual Learning on Benchling

A Practical Guide for Instructors

benchling.com

Why are we writing this guide?

As social distancing practices are utilized to curb COVID-19 transmission rates, university courses have been disrupted worldwide. Semester-long plans for in-person classes and exams have been foregone as science educators scramble towards remote teaching approaches. While the transition of lectures and assessments to a digital format has seen some success with video conferencing software like Zoom and learning management systems like Canvas, digitizing experimental coursework is a greater challenge. Lab courses generally rely on wet lab work, teach a variety of molecular biology techniques, and involve active collaboration and discussion among faculty and peers. All of these factors make it difficult to adapt to a virtual environment. But with the right tools, students can build some of the same skills and achieve the key outcomes they would in an in-person lab course.

This guide to using Benchling for virtual learning will help instructors overcome some of the challenges they are facing at the moment. We explain why Benchling's platform makes an excellent virtual learning tool, describe how it encompasses student-centric learning styles, and provide actionable ideas to help get you started.

Who should use this guide?

This guide will be most relevant to instructors teaching laboratory courses in molecular biology and other related disciplines — biochemistry, bioengineering, bioinformatics, microbiology, genetics, and so on. We recommend using Benchling with an advanced undergraduate or early graduate student audience, but it would be suitable for any students with a fundamental knowledge of molecular biology.

Table of Contents

Benchling as a Virtual Learning Platform

What is Benchling?

Benchling is a **free**, cloud-based software platform for individual academics, academic labs, and classes to design, record, and analyze experiments. Adapted as a virtual learning tool, it can help emulate the scientific process without being in the lab, allowing you to walk students through each step of an experiment and providing ample opportunities for hands-on, exploratory learning. While we recognize that virtual solutions are not a substitute for practical wet lab experience, familiarity with Benchling has key benefits that extend far beyond the classroom.

Key Advantages of Benchling for Virtual Learning

- Benchling is an intuitive platform for designing and analyzing experiments, including two main applications: Notebook, an electronic lab notebook, and Molecular Biology, a suite of sequence design and analysis tools.
- Benchling allows your students to find instructions, capture notes, and compile sequences in silico in a single place, making it easy for you and your students to centralize coursework.
- Benchling is a highly transferable skill for your students' next step, whether they pursue careers in medicine, academia, or industry.
- Benchling is virtually accessible to all of your students; all they need to get started is a laptop with an internet connection.
- Benchling has a dedicated help center full of tutorials that can answer questions you or your students have in real time.

Learning with Benchling Notebook and Molecular Biology

Benchling Notebook

For students

Benchling Notebook is an intuitive and cloud-based electronic lab notebook for students. They can record their experimental notes and data and centralize the resources they collect — from protocols and data tables to sequences and image files. Notebook entries can also be easily shared and edited between students, facilitating group learning and discussion.

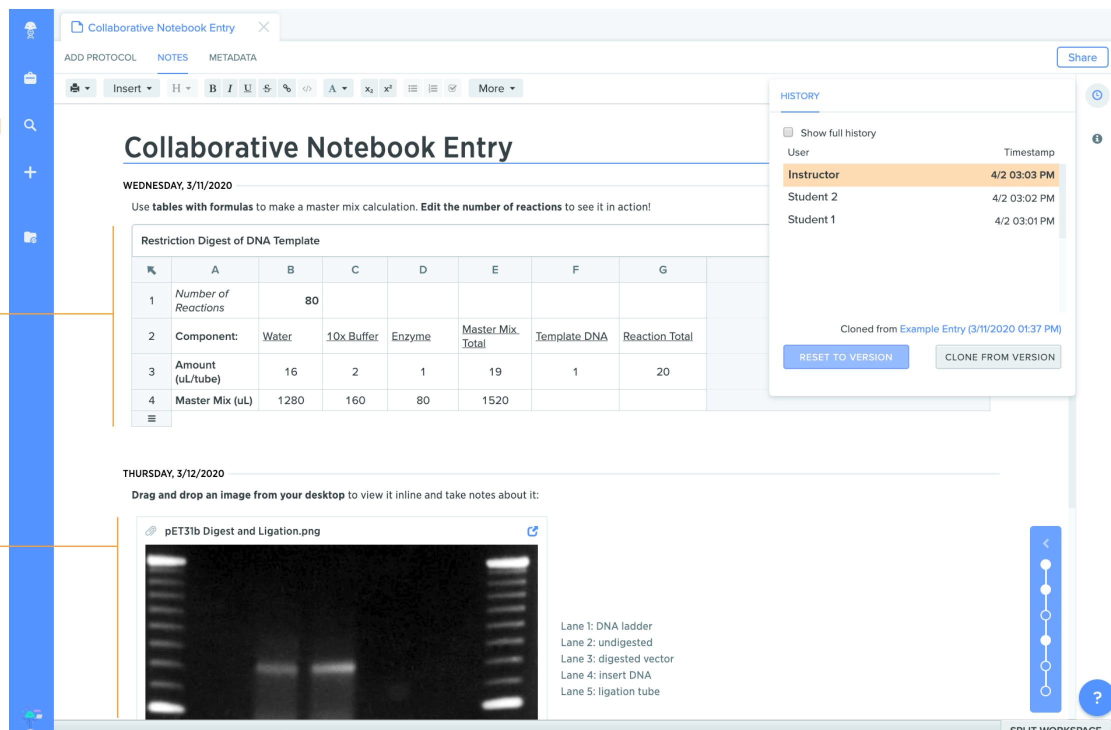
For instructors

As an instructor, you can design laboratory modules through prepopulated Notebook templates. You may even insert a dataset for your students to analyze independently or collaboratively. Because Notebook entries are timestamped and on the cloud, you have complete transparency. You can review your students' entries in real-time, or you can have students export entries as PDFs and submit them to you electronically.

Searchable notebook entries

Built in tables with formulas

File attachments / previews



Version history of editing by students

Additional notebook features:

- Customizable Notebook templates
- PDF export of entries
- @-mentioning of users, sequences, and entries

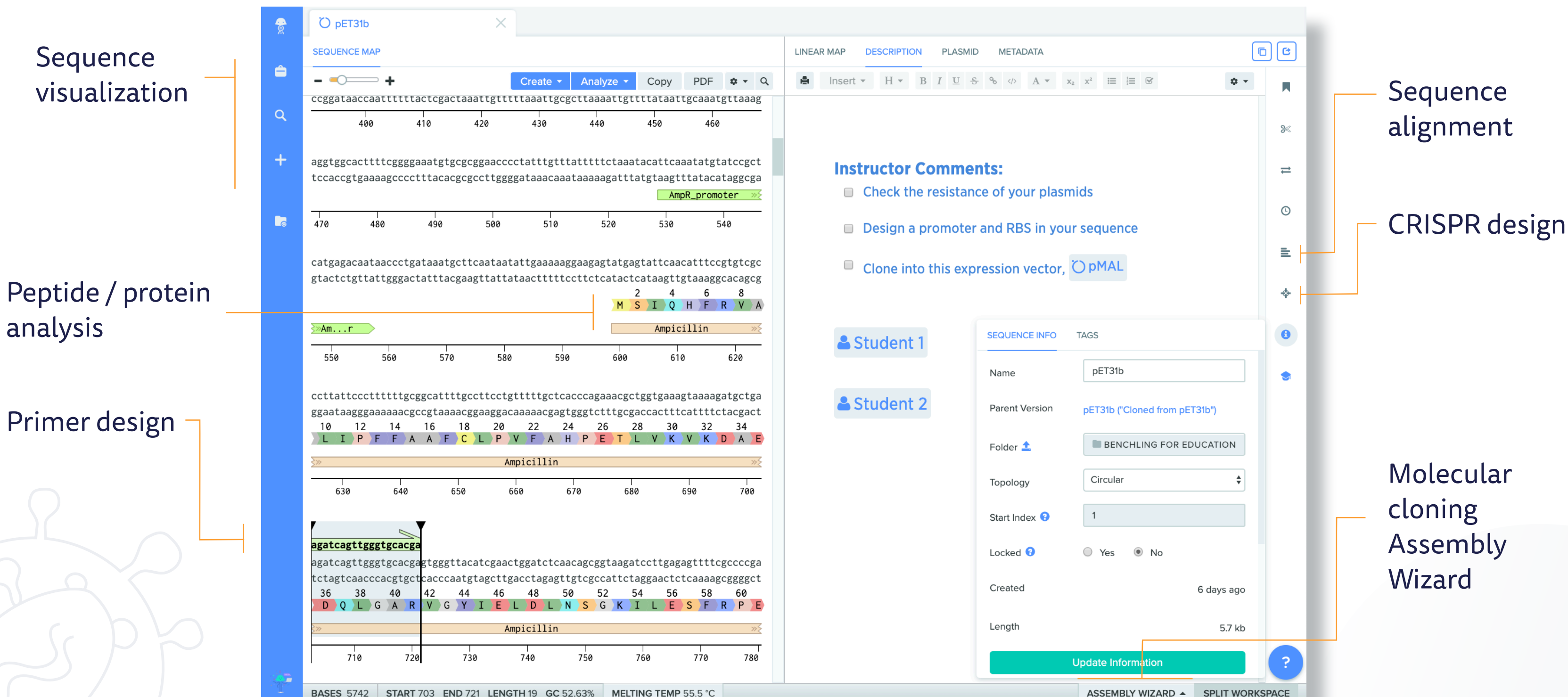
Benchling Molecular Biology

For students

Benchling Molecular Biology provides over 10 sequence design and analysis tools. Students can learn to design primers, model PCR and cloning in silico, score CRISPR guide RNAs, analyze sequence alignments, and more. In addition to these tools, any sequences students design and generate can be shared with their peers to review or edit.

For instructors

As an instructor, you're providing students with a diverse toolset for design and analysis that scientists use every day – emulating an authentic scientific process. With advanced tools in Benchling, like CRISPR guide RNA design or codon optimization, you can integrate new concepts that extend student learning. Similar to the Notebook, you also have complete transparency and can give students feedback about their sequence designs. You can import sequences from external databases (NCBI, Addgene, Ensembl) or from an organism's genome, making it easy to prepare content for course modules.



Student-Focused Learning with Benchling

While there are a variety of active learning approaches in biology education, we describe two strategies that work well with Benchling's platform. We introduce and later expand on four course modules that utilize these approaches.

PROBLEM-BASED LEARNING

Design molecular biology scenarios with key tasks and deliverables from your students.
The example course module, "The Basics of Primer Design for PCR (p.8)," explores how you can prompt students to design primers and model PCR for specific genes in an organism. You can adapt this approach for a number of molecular biology techniques, where open-ended prompts will allow students to develop problem-solving skills as a scientist.

Populate experimental datasets that your class can access through Notebook templates and sequence imports.
Have students analyze these materials and report their own interpretations of the data. Another module, "In Silico Analysis of DNA and Protein Sequences (p.10)," describes how you can use this method to introduce students to bioinformatic analysis. Given a set of sequences, students will determine sequence homology, validate potential ORFs, and identify putative proteins.

INQUIRY-BASED LEARNING

Compile various laboratory techniques, and have students investigate and evaluate techniques they're interested in.
In the example course module "Investigating Molecular Cloning Methods: Restriction, Gibson, and Golden Gate (p.12)," students drive their own learning through investigating a particular cloning strategy. Having students teach a technique to others will allow them to master it for themselves.

Model the scientific process by asking students to design mock experiments and include methodology, materials, and references
The module "How to Use an Electronic Lab Notebook (ELN) (p.14)" showcases the power of ELNs as students develop protocols and analyze experimental data. Students can read and analyze peer-reviewed literature, evaluate experimental workflows used to obtain published data, and recreate protocols as if they were performing experiments themselves.

"For the first time, I invited 35 students to keep an ELN in Benchling. This was the best choice I made this semester. Normally, I dread reading handwritten, image-stapled notebooks. However, this semester, every Notebook seemed professional, clear, and inviting. I also noticed students were more positive about their efforts and took more time to add photos and results." *-Harley, Adjunct Professor, University of Maryland*

PROBLEM-BASED LEARNING MODULE

The Basics of Primer Design for PCR

Primer design and PCR are two essential skills taught in every molecular biology lab course. Benchling helps students learn how to design primers and model PCR in a way that emulates what they would do experimentally. In this example, we'll describe how your students can employ the primer design tools in Benchling to isolate a gene of interest from a model organism given a sample of DNA. Lessons like this produce specific, accessible deliverables from students that allow you to identify gaps in their understanding.

STUDENT LEARNING OUTCOMES

1 / Design primers effectively and in real-time

2 / Utilize secondary structure analysis of primers as a design principle

3 / Standardize primer design using robust software calculations

4 / Simulate PCR and analyze PCR products

5 / Capture and record every step of this scientific workflow

Getting This Module Started on Benching

1. Create a research prompt where teams of 2-4 students investigate how to isolate a particular gene from an organism. Ensure that the organism's genome can be imported or is already uploaded to Benchling's database.
2. Assign each team a different gene and challenge them to obtain the DNA sequence into Benchling from a method of their choosing.
3. Populate Notebook templates for students and have them follow a set of tasks. For instance, ask students to gather information on their gene of interest such as 1) accession number, 2) gene context / biological pathway, and 3) sequence length.

4. Ask students to manually design primer pairs that would isolate their specific gene from genomic DNA if they were using PCR.
5. Ask them to tabulate primer properties and secondary structure prediction values from Benchling in a Notebook entry.
6. Finally, have them simulate PCR, describe how to analyze PCR products on a gel, and deposit the final PCR products along with their primer pairs as sequences for you to review or grade.

Tools and Analysis within Benchling

- Secondary structure prediction for nucleotides (homo- and mono-dimers)
- Automatic primer design based on the Primer3 wizard
- Drag-and-click / manual primer design
- Thermodynamic parameters and nucleotide properties (GC content, Length, Melting temperature)

PROBLEM-BASED LEARNING MODULE

In Silico Analysis of DNA and Protein Sequences

Fundamental in silico analysis is often used in molecular biology research but it can be challenging to teach in laboratory courses. This is often due to complex analysis, which can be challenging for students to pick up. Benchling makes these analyses more accessible to students by simplifying multiple tools into a web interface that help students answer scientific questions and collect insights. Our example discusses a way for students to grasp introductory principles of bioinformatics by performing sequence alignments and BLAST searches for DNA sequences. Meanwhile, they will acquire deductive reasoning skills.

STUDENT LEARNING OUTCOMES

1 / Learn basic principles of sequence analysis as an introduction to bioinformatics

2 / Translate DNA sequences into protein sequences

3 / Infer DNA and protein sequence homology through alignments

4 / Create a consensus sequence from a given set of sequences

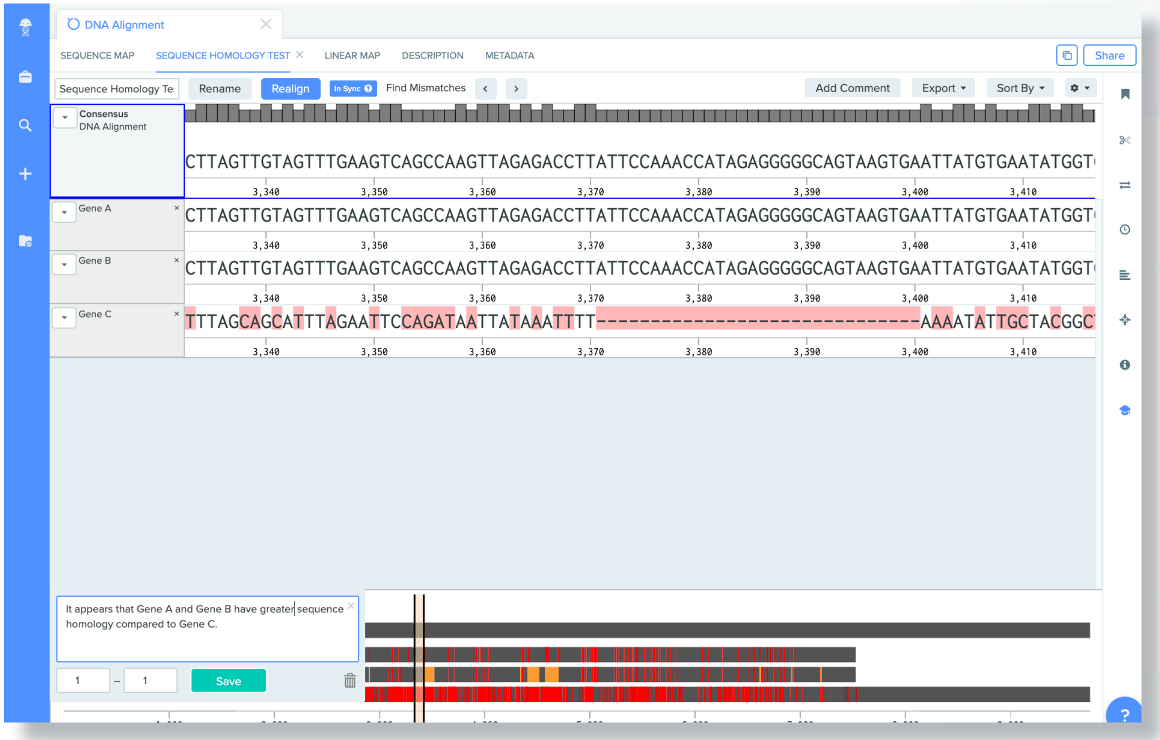
Getting This Module Started on Benchling

1. Import DNA sequences for five different genes into Benchling and ensure some sequences belong to a known gene family. Remove any identifying information or annotations and relabel these sequences as 'Unknown A," "Unknown B", and so on.
2. Inform your students that these sequences were collected "experimentally" and that they will use them as a starting point for in silico analysis.
3. Within a Notebook template, link these five sequences and provide a set of analyses you want the students to perform on them. For example, you might have them perform DNA sequence alignment, DNA-to-protein translation, and protein sequence creation and alignment.

4. Based on their analyses, ask students to determine which sequences are likely homologous. Have them create and store a consensus sequence in DNA and protein formats using the homologous sequences.
5. Finally, have them open all five unknown sequences and perform a NCBI BLAST search in Benchling to assess if they have been observed in nature. Ask them to annotate these sequences in Benchling with accession ID and organism.
6. From NCBI, ask students to investigate the accession IDs for all five sequences and classify each a known gene, putative gene, or unknown gene.
7. Have students create a table in a Notebook entry compiling all sequences (with hyperlinks) and related information. They should submit the Notebook entry for assessment.

Tools and Analysis within Benchling

- Sequence imports from external databases or various file formats
- DNA and protein sequence alignments
- NCBI BLAST searches for DNA sequences
- Sequence annotation



Investigating Molecular Cloning Methods

Restriction, Gibson, and Golden Gate

Molecular cloning is a critical foundation for modern biology education, but the various methods are often taught through rote memorization rather than practice. In this module, we'll discuss a virtual lesson that motivates students to learn by doing.

STUDENT LEARNING OUTCOMES

1 / Understand design principles and considerations for molecular cloning

2 / Learn how to obtain and import sequences from external databases

3 / Extract protocols from reagent manufacturers

4 / Identify trade-offs between each method of cloningof this scientific workflow

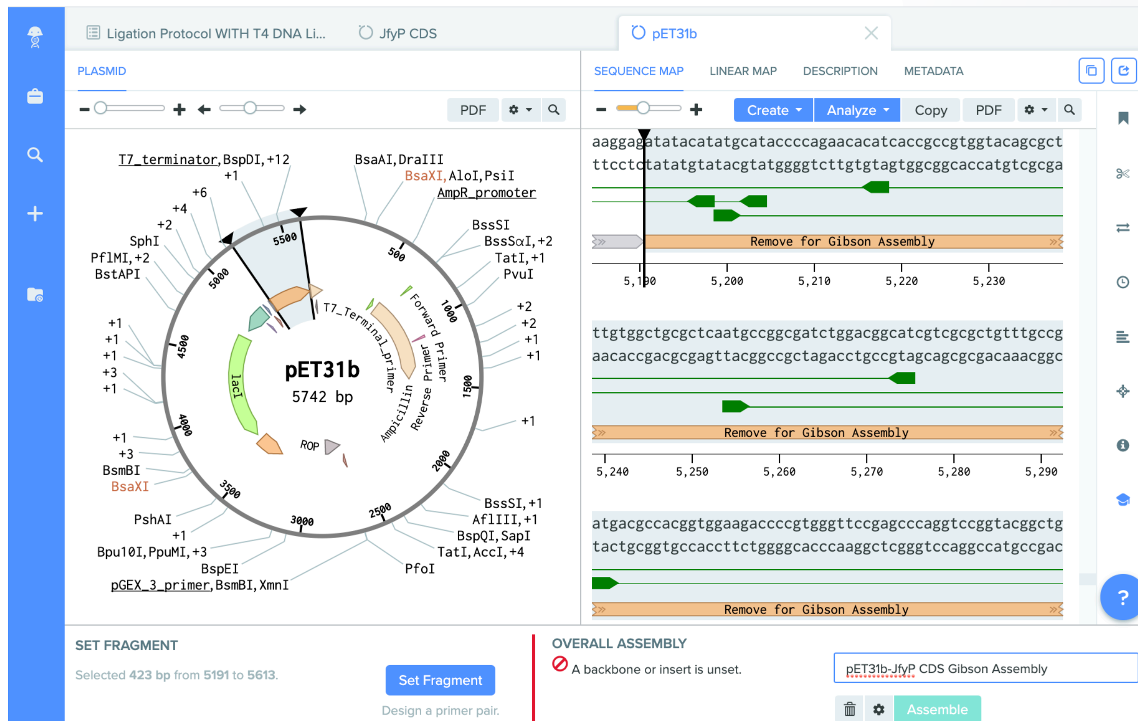
Getting This Module Started on Benchling

1. Create a list of molecular cloning techniques that you will have students choose from. For this example, we'll use the three strategies of restriction, Gibson, and Golden Gate cloning, all of which are natively supported on Benchling.
2. Arrange students into groups of six, and then into pairs. Each pair should be assigned a different cloning technique to investigate.
3. Provide a model insert for each group to use, but have them determine a suitable backbone vector to use. Have each pair find a suitable vector on a database like Addgene and have them import it into Benchling.
4. Task each pair to use their respective cloning strategy to design the desired construct (manually and/or by using Benchling's Assembly Wizard). Have them find and attach experimental protocols from established reagent

5. Ask every pair to show other members of their group how they designed and generated their construct on Benchling.
6. The entire group should evaluate one another's methods, discuss the pros and cons of each method, and recommend situations where each method would be appropriate.
7. Evaluate your entire class by giving them a new, standard set of inserts and vectors where they'll utilize each cloning method to generate constructs for assessment.

Tools and Analysis within Benchling

- Sequence visualization and annotation for manual cloning
- Restriction cloning assembly wizard with primer design to incorporate restriction sites
- Gibson cloning assembly wizard with primer design to add sequence complementarity
- Golden Gate cloning assembly wizard with primer design for including BsaI sites



How to Use a Modern Electronic Lab Notebook (ELN)

In many science courses, lab notebooks are still taught to students in outdated paper formats despite the current trends that research is transitioning to electronic note-taking. Benchling's Notebook serves as a model cloud-based ELN for laboratory education; it has an intuitive interface with features that make it easy to build and share protocols, attach and preview files, and organize entries for collaboration. This example module will showcase how to use electronic lab notebooks to engage with published research literature in ways that paper notebooks cannot and to simplify the process of experimental collaboration.

STUDENT LEARNING OUTCOMES

1 / Understand novel research techniques relevant to other course topics

2 / Organize relevant scratch notes, analyses, and observations in an ELN

3 / Pinpoint the underlying experimental steps that produced published figures

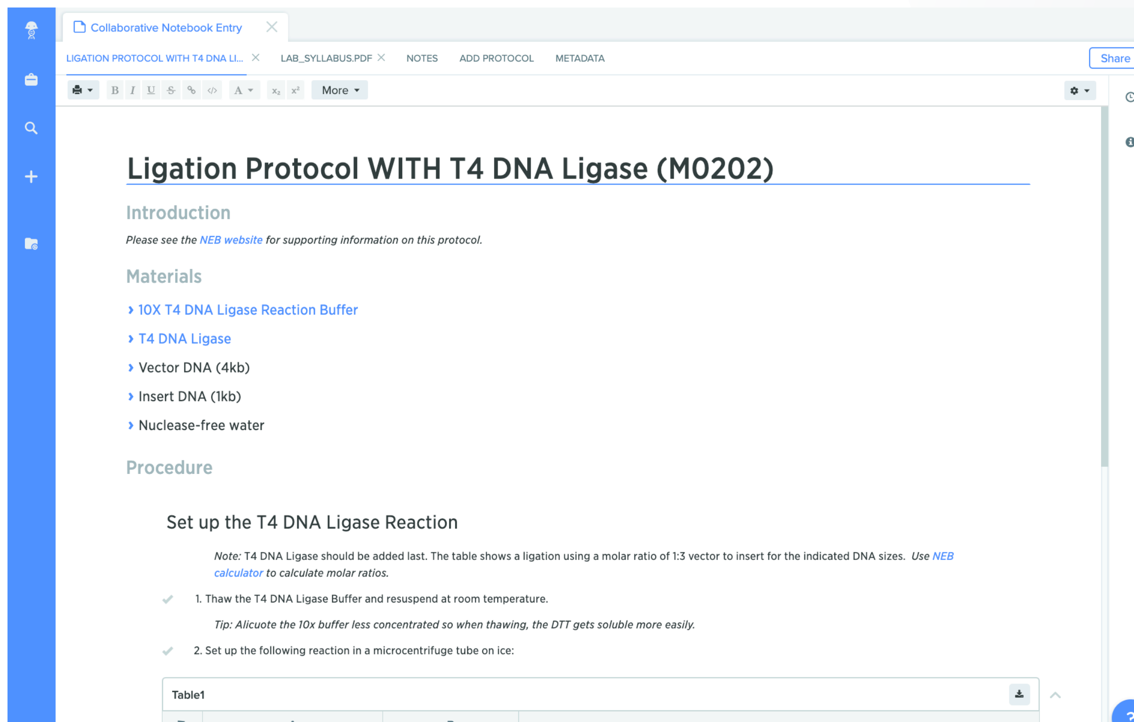
Getting This Module Started on Benchling

1. Compile a list of research articles that are relevant to core concepts in your course. For this example, let's assume you've taught your class about "fluorescence" and therefore have compiled seminal research articles within that field: FISH, fluorescence probes, fluorescence imaging, and so on.
2, In teams of 2-4 students, have each team analyze a different article and use Notebook templates to record answers to prompts. Those prompts may be: 1) Write a short summary of the article, 2) Analyze each main figure, and 3) List key experimental steps to obtain the data in each figure.
3. Have students attach the research article, supporting information, and other relevant files inside the Notebook entry for easy referencing.

4. Now, ask teams to recreate protocols on Benchling as if performing the experiment themselves, including hyperlinks to sequences, references, and attachments if needed.
5. Review these entries and protocols to gauge each team's understanding of a technique.
6. Have teams swap their protocols with another. Ask them to assess each other based on the clarity of instructions provided. Explain how this process emulates modern scientists sharing their protocols with their external collaborators.
7. Finally, ask students to deposit their work into a shared class folder, creating an internal protocol repository like one that a research lab would have.

Tools and Analysis within Benchling

- Prepopulated Notebook entry templates
- File attachments and previews
- Collaborative entry editing
- Built-in protocols



Potential Modules for a Virtual Lab Course

While we've provided four actionable ideas, there are many other ways Benchling could be incorporated into a virtual lab course. We've provided a list of course modules that are commonly taught in molecular biology labs and are also well-supported by Benchling. Topics that have already been described are in **bold**.

- Science Basics and Literacy
  - **How to Use a Modern Electronic Lab Notebook (ELN)**
  - **In Silico Analysis of DNA and Protein Sequences**
- Basic Molecular Biology Techniques
  - **The Basics of Primer Design and PCR**
  - Gel Electrophoresis
  - Bacterial Transformation
  - Mammalian Transfection
  - **Molecular Cloning Methods**
    - Restriction
    - Gibson
    - Golden Gate
- Advanced Molecular Biology Techniques
  - CRISPR Guide RNA Design
  - Peptide/Protein Analysis
  - Codon Optimization

How To Set Up Your Class in Benchling

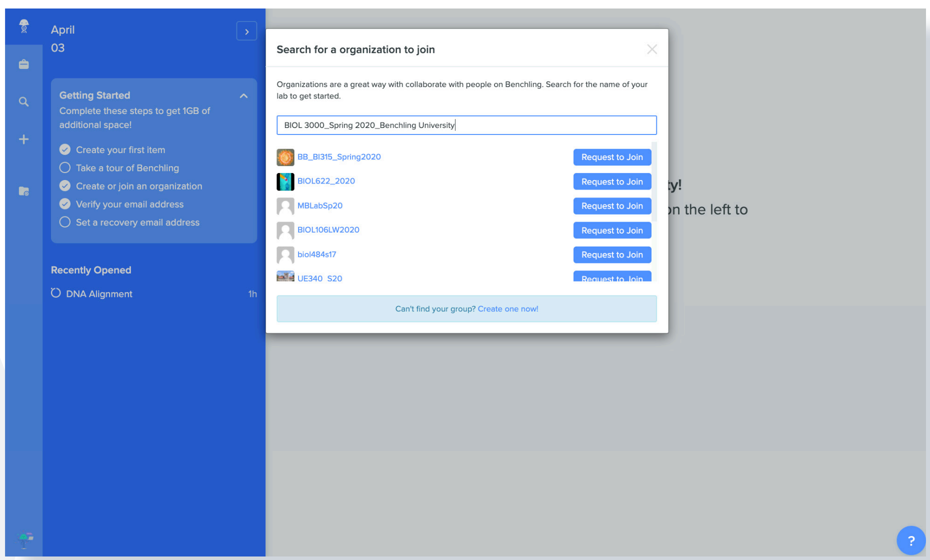
Now that you know the benefits of Benchling as a virtual learning tool and have these example course modules in your back pocket, start setting up your class in Benchling now!

Step 1. **Sign up for a free account.** Visit the link below. Instructors that sign up with this special link receive 10 extra GB of storage space.

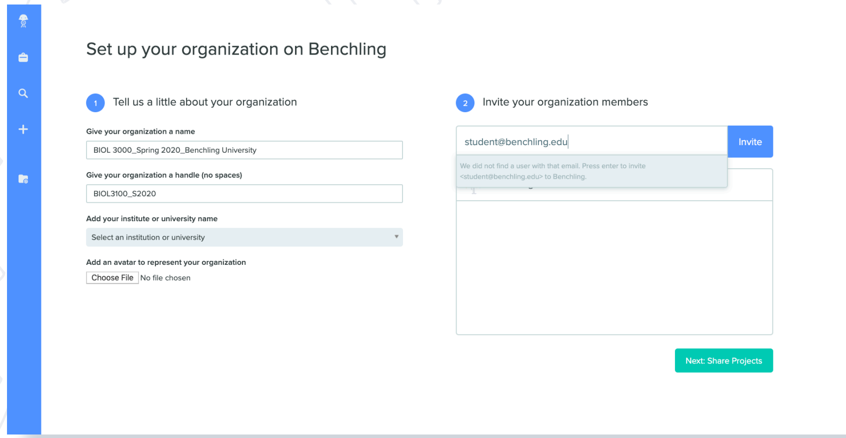
Get started

or visit: https://benchling.com/promo/VIRTUALLAB20

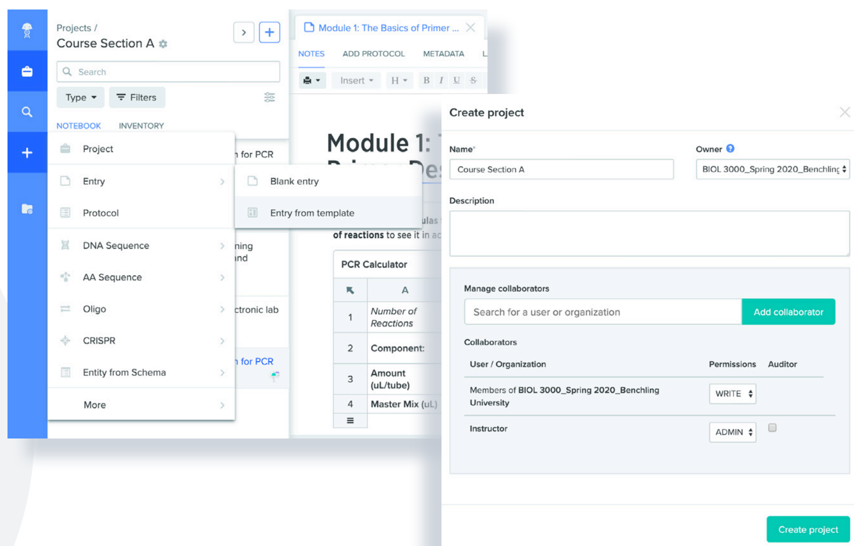
Step 2. **Create an organization for your class.** Organizations are a great way to manage data from across all your students. Members of an organization can access entries and sequences generated by one another, streamlining team-based learning.



Step 3. **Invite your students to join your Benchling organization.** Using their school emails, invite your students to join your Benchling organization. They will receive an email with a direct link to sign up and join your organization.



Step 4. **Organize course sections and content with Benchling projects.** Structure Benchling projects to correspond to your teaching needs. For example, if you have multiple course sections or groups, create a different project for each. You can grant individual students access to specific projects. You can add Notebook entries to projects, or organize folders within projects. For example, folders might correspond to virtual lab modules that you plan to cover.



Conclusion

We've introduced various ways that you can get started on Benchling and adapt your lab course quickly in the current situation. Virtual lab courses are not a substitute for practical wet lab experiences, but we developed this guide to show how Benchling can help during this time. When these uncertain times do come to an end, Benchling can still be a resource for physical laboratory courses. We hope this guide leaves instructors with innovative and exciting ways to incorporate modern tools into their courses, virtual or not.

Benchling

benchling.com