A STEP BY STEP GUIDE:

How to Implement Virtual Labs into Teaching Chemistry.

Beyond Labz

Using a Virtual Lab in a classroom setting

Virtual labs are a great resource for any elevated classroom. Students have the freedom to explore laboratory work without fear of failure or additional cost to the institution. Incorporating virtual labs can occur at any step in the teaching process. This guide covers a step by step structure of a classroom or laboratory environment and provides ideas of how virtual labs can be used in each step. It should be noted that it isn't expected to use virtual labs at every step of the learning process - but virtual labs from Beyond Labz can be an invaluable tool in the process of learning chemistry.

You'll find the steps and recommendations below helpful regardless of the structure of your class.

STEP 01:

INTRODUCE STUDENTS TO THE MATERIAL BEFORE CLASS.

Incorporating a pre-lecture assignment or pre-lecture video will provide students with an initial exposure to the lecture topic(s). The more students are exposed to the material, the better their retention of that material will be.

The most common way to introduce material before it is discussed in the classroom is through a combination of an introductory video and practice problems. However, you should take this approach in a manner that is most comfortable for your teaching style. Many learning management systems have the ability to include a video as a part of a series of questions students are assigned.

To use Beyond Labz as pre-lecture material you could have students perform a lab before you discuss the results of that lab in class. For example, you could have students complete Rutherford's experiment and use the Beyond Labz pre-built activity to jump-start their thinking about how Rutherford's experiment proves the existence of a dense nucleus. Students would have performed the experiment prior to the discussion, which will lead to a richer understanding of the significance of Rutherford's experiment and the implications of its results.

Woodward, R. L., & Reid, C. S. (2019). You've got mail (and homework): Simple strategies for promoting student engagement with prelecture videos. Journal of Chemical Education, 96(9), 2055–2058. https://doi.org/10.1021/acs.jchemed.9b00315

STEP 02:

TEACH THE MATERIAL DURING CLASS – ADD FORMATIVE CONTEXT-RICH PROBLEM SOLVING TO THE LECTURE.

Engaging students during a class lecture or discussion will allow the instructor to make corrections or emphasize difficult concepts on the fly. Have some type of formative assessment to provide instant feedback to the instructor allows them to know when a concept has been understood by their students or if it needs more clarification.

A common way instructors choose to incorporate this type of engagement with their students is through the use of clicker questions. This can be done with many different devices and software - and the commonality of smartphones, tablets, and laptops in the classroom makes it even easier to implement this type of strategy. One key element researchers have found to increase the effectiveness of this learning tool is to make questions more context-rich. This can be done via story problems or using a simulation to add real-world complexity (and not complexity for complexity's sake) to the assessment.

Beyond Labz can be a great tool for formative assessments during lectures. An instructor could have their students perform a quick experiment and gather the results from their students in real time. For example, an organic instructor could ask their students to use Beyond Labz to synthesize a specific molecule from a set of starting materials. Students could select their starting materials and report them to their instructor. Students could then perform the synthesis (much more quickly thanks to the ability for our organic synthesis lab to fast forward time) and report on the product they created. The instructor could then lead a discussion about the different starting materials students chose and how they lead to the products created - desired or not.

> "My name is John Boom. I am a high school chemistry teacher and let me just offer you tremendous praise for your work with the virtual chemistry lab. I think it's wonderful! I am having my students replicate Nobel Prize winning experiments to help them understand the structure of the atom. Your program gives my students the ability to do labs they would never have been able to do on their own. Great work! Great concept! I love it. All praise to you and your team."

STEP 03:

INCORPORATE A FOLLOW-UP ASSIGNMENT TO LECTURE THAT REINFORCES THE CONCEPTS COVERED IN THE PRE-LECTURE AND LECTURE.

A follow-up assignment is part of the vintage classroom experience - and for good reason. Having students evaluate their understanding of the material is essential to helping them master it. This also provides the instructor with the ability to evaluate their students' learning progress in the course.

This element of instruction is often included in some type of post-lecture homework assignment, but could also be incorporated using a group project, laboratory, paper, or other project-based assignment. Instructors should choose a method that works best for them, but utilizing a method that gives feedback as students progress through problems can be beneficial to cementing student understanding.

Beyond Labz can be a great follow-up assignment for students. After teaching students how titrations work, an instructor could assign students a series of titrations to complete in Beyond Labz. Students could utilize the practice unknown feature of Beyond Labz to practice titrations and get valuable feedback on their mistakes and successes. Students would then be able to complete the assigned unknown from their instructor with confidence.

> "...Beyond Labz is a find. I expect we will continue to use it after the epidemic. The original purpose of Beyond Labz was to provide a complement to face to face labs. Besides all the presets, you can set up and do pretty much whatever you want with it, so it allows you to launch your students on open ended queries."
>
> Karel Pluhar
> Community College System of New Hampshire

STEP 04:

FINISH EACH WEEK (OR UNIT OR CHAPTER) WITH A SUMMARY QUIZ OR ASSIGNMENT THAT INCORPORATES METACOGNITION.

This seemingly simple practice can have a significant impact on the understanding and performance of typically lower-level students. Research at the University of Utah found that incorporating metacognition into students' routines help students understand what they don't know and provide them with a clear guide on how they can improve their understanding.

The simple way to implement this is to have students predict the score they will get on a quiz they are about to take. By having students predict their level of understanding before taking an assessment, they will begin to understand what they do and do not know. After the assessment is taken, a comparison of the score they predicted and the score they earned could be provided along with a summary of their strong and weak points.

Incorporating metacognition can be done with almost any type of assessment and Beyond Labz is no exception. Beyond Labz could be used as a summary assessment of topics discussed during the week. For example, after discussing a specific aspect of calorimetry, students could be assigned a lab directly assessing the topic discussed. Students could be asked to predict their score in the lab and compare that with the score they actually receive. Feedback could be provided to the student to help them understand what they understood and what they needed to study further.

Casselman, B. L., & Atwood, C. H. (2017). Improving general chemistry course performance through online homework-based metacognitive training. Journal of Chemical Education, 94(12), 1811–1821. https://doi.org/10.1021/acs.jchemed.7b00298

In-class teaching - Conclusion:

Incorporating best teaching practices in any learning environment will help students obtain a mastery of the material presented to them. Utilizing the tools from Beyond Labz, instructors can be confident in allowing students the freedom to explore as well as breaking the monotony of traditional course structures. One of the best tools instructors have at their fingertips is other instructors! Beyond Labz has a community built for instructors not only to share the things they do with our software, but also provide a place to share best practices, including lesson plans, course structure ideas, videos, and many more! We would love to welcome you to our free community and thank you for using Beyond Labz!

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I would also like to let you know that Beyond Labz worked very well for us over the 2 semesters this summer and almost every student commented on how much they liked it. I felt that it showed a relatively close representation of what students would have done in the lab and the ability for them to generate their own results and make choices in a low-stress and safe setting has been great for them to connect lecture concepts with lab techniques.

So thank you for creating something that has really made virtual labs possible in this uncertain and unusual time.

Haley Albright
University of Michigan

Using a Virtual Lab in an in-person laboratory setting

Laboratory - we often observe that classic laboratory work often doesn’t reinforce scientific concepts but rather teaches students laboratory skills and techniques. To provide reinforcement of scientific concepts as intended, we recommend the following process for a laboratory structure.

STEP 01:

PROVIDE STUDENTS WITH A PRE-LAB ASSIGNMENT TO PREPARE THEM FOR THE LAB.

Pre-lab assignments are classic aspects of any laboratory structure. Typically pre-lab assignments focus on providing students with practice on difficult calculations or ask them to apply theoretical thinking to what is being done in the laboratory that week. An ideal pre-lab assignment would allow students to experience as much of the lab as possible in order to give them confidence in their laboratory work.

Beyond Labz has proven to be an invaluable tool for pre-laboratory work. Using Beyond Labz, students can complete a lab virtually before they even enter the classroom. When Beyond Labz has been used as a pre-lab, instructors have reported students performing better in the laboratory, wasting less time, and being more efficient with their chemicals. Students also typically ask more in-depth questions about the substance of the lab rather than procedural questions to complete the lab.

Woodfield, B. F.; Catlin, H. R.; Waddoups, G. L.; Moore, M. S.; Swan, R.; Allen, R.; Bodily, G. The Virtual Chemlab Project: A Realistic and Sophisticated Simulation of Inorganic Qualitative Analysis. Journal of Chemical Education2004, 81 (11), 1672.

STEP 02:

PROVIDE STUDENTS WITH A PRE-LAB LECTURE TO COVER THE BASICS OF THE CONCEPTS FOR THAT LAB.

A pre-lab lecture is very similar to a pre-lab assignment, but the lab instructor or lab coordinator provides a lecture in addition to a pre-lab assignment. A pre-lab lecture typically focuses on safety aspects to consider in the laboratory that week, examples of calculations students might be performing, and perhaps a more in-depth exploration of the background of the experiment being performed.

Incorporating any type of active learning into a lecture will help students stay engaged and give the instructor feedback into what students are and are not understanding. This is often done using some type of formative assessment via a clicker device or system. Instructors can use the system to ask students questions and be able to provide real-time instructional adjustments based on student responses.

Beyond Labz can be a very powerful tool in any lecture environment. Not only could an instructor ask a student a question to gauge their understanding, but they could actually have students perform a part of the experiment (or possibly the entire experiment if the lab can utilize the fast-forward feature of Beyond Labz) during lecture and report their findings. This type of back-and-forth between instructor and learner incorporates a style of learning that encourages mastery over regurgitation.

> Overall, the software has been a really nice substitute for the "real deal". And, shockingly, I've not heard a single complaint from students about using the software. That is a really good sign because they tend to complain about lots of things....
>
> Kevin Pate
> McCoy Professor
> Chemistry
> BioChemistry
> Marietta College

STEP 03:

HAVE STUDENTS PERFORM THE LAB.

The most important of any laboratory course is the laboratory experiment itself. Ideally, students are able to perform the wet labs in the manner designed by the institution and instructor. While labs do tend to focus more on students gaining understanding of how to use instruments, the skills developed in the laboratory are necessary for any successful chemist.

Beyond Labz was designed and is meant to be used as a lab supplement. However, extenuating circumstances that are now all too familiar could necessitate a wet laboratory experience being substituted for a dry or virtual one. While the pandemic looms top of mind for most of us, things such as building destruction (in the case of fire or flood), renovations , limited lab space, or limited budgets could be reasons to have lab replacements at the ready. While we hope this never happens, having a plan in place if it does ensures a smooth transition for students and instructors. Beyond Labz can also be used to perform experiments that otherwise couldn't be performed due to cost or practicality - experiments such as Millikan's Oil Drop experiment or Thompson's Cathode Ray tube experiment.

Beyond Labz can be used as a lab replacement in these types of circumstances. The open-ended nature of the simulations allows instructors to get the closest possible experience to a real laboratory. Equipment, compounds, and environments are modeled after actual laboratories. In most cases, images and spectra found in Beyond Labz are from actual compounds. The labs even include things such as instrument errors, changes in pressure, and activity coefficients. If a lab replacement is necessary, Beyond Labz is the place to do it!

"I have found this program has been a great asset for my students. Most of my students enjoyed the experience. In my online chemistry lab, the students were a little skeptical about how the lab would be online. Very quickly, they saw that the experiments were mostly the same as the students working in the lab. We could match the curriculum and provide a good learning experience. The students were shocked when they each had unique data. That lead to a natural discussion of error and uncertainty. The students liked being able to repeat the experiment if they were uncomfortable with the results – or if they had made a major mistake.

In another class I used the program for lab and also for basic concept development for the lecture. The students enjoyed the activities. One likened it to a video game for chemists. I liked that I could give the students some freedom to try things we would not normally do because of cost, waste, time, etc."

Nancy Weber
Rider University

STEP 04:

HAVE STUDENTS COMPLETE A POST-LAB ASSIGNMENT THAT FOCUSES ON THE DATA/ CONCEPTS LEARNED IN THE LAB BUT ALSO INCLUDES QUESTIONS THAT ASK STUDENTS TO DIVE DEEPER VIA A SERIES OF "WHAT IF" QUESTIONS.

Post lab activities most often have students complete calculations based on data collected during the lab period. Once students have this information, they are often asked to interpret that data and think about the "what-ifs" of the experiment and how those what-ifs might change their results. Post-labs typically help hit home the reasons behind performing the experiment as well as attempting to help students develop a deeper conceptual understanding of the material.

Beyond Labz can be used to magnify this desired effect even further. Instead of just having students think about the what-if questions - they could perform them. In an ideal laboratory, students would have unlimited resources and time to be able to complete the desired experiment and explore variations to deepen their understanding. Unfortunately this type of approach would be too time consuming and/or too expensive. However, if students have a virtual environment - they can do just that. They can perform experiments over and over with the freedom to fail and explore. One powerful example of this would be Rutherford's experiment. Being able to perform Rutherford's experiment would be a unique thing for any student, but being able to substitute the gold foil for something else, such as sodium, would be an amazing exploration opportunity. This can be done with Beyond Labz!

Woodfield, B. F.; Andrus, M. B.; Andersen, T.; Miller, J.; Simmons, B.; Stanger, R.; Waddoups, G. L.; Moore, M. S.; Swan, R.; Allen, R.; Bodily, G. The Virtual Chemlab Project: A Realistic and Sophisticated Simulation of Organic Synthesis and Organic Qualitative Analysis. Journal of Chemical Education 2005, 82 (11), 1728.

In-lab teaching - Conclusion:

Beyond Labz quickly becomes a go-to tool for instructors to use in their laboratory teaching. It can be used in any aspect of the laboratory process - as a pre-lab, post-lab, or even lab replacement. Beyond Labz was designed as a supplement to laboratory work and will add value to a traditional lab structure. Traditional labs can be replaced with virtual labs if circumstances require it, but labs that instructors only dreamed of being able to do with their students are now possible with Beyond Labz. We look forward to the amazing ways you'll incorporate Beyond Labz into your instruction and encourage you to share your experience with fellow instructors on our community site.

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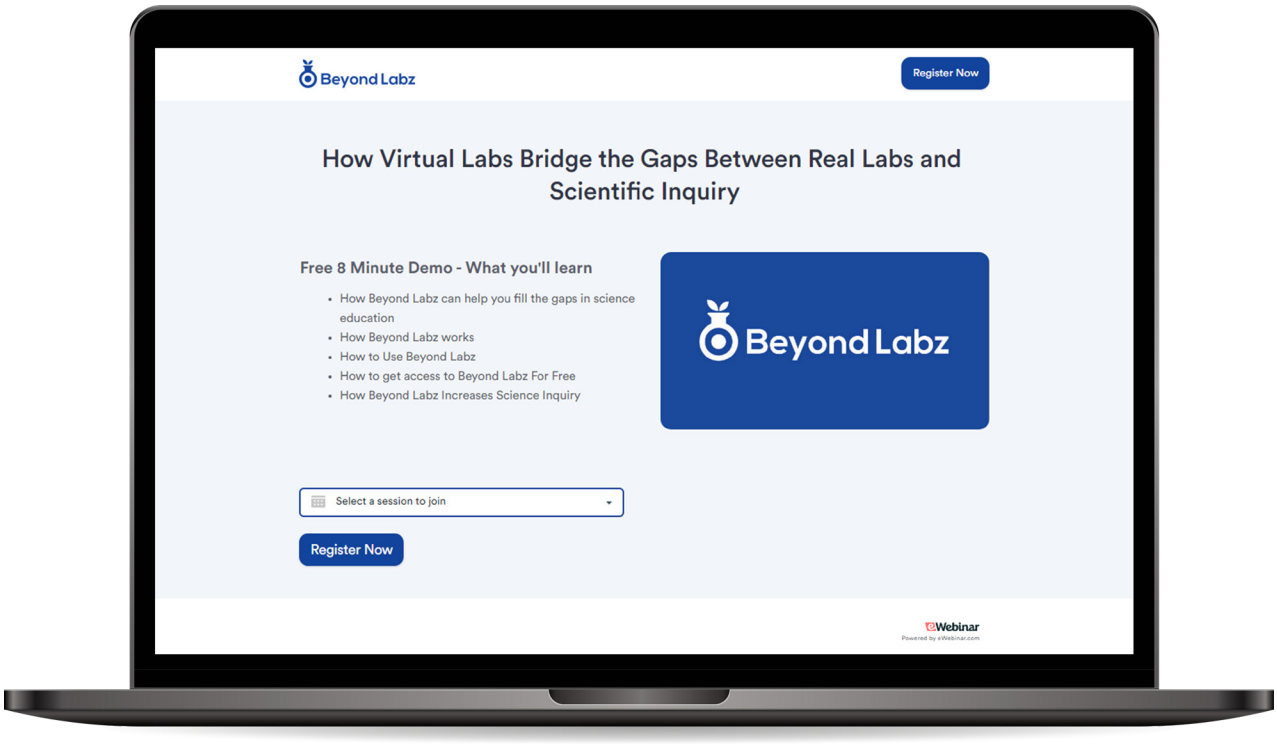
"I just wanted to say I'm in love with the experiments in Beyond Labz."

Dr. Keneshia Johnson
Assistant Professor
Alabama A&M



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  Hannel, Stacey L. and J. Cuevas. "A Study on Science Achievement and Motivation Using Computer-based Simulations Compared to Traditional Hands-on Manipulation." (2018).

ARTICLE SOURCE:

- Equivalence of using a desktop virtual reality science simulation at home and in class
  Makransky G, Mayer RE, Veitch N, Hood M, Christensen KB, et al. (2019) Equivalence of using a desktop virtual reality science simulation at home and in class. PLOS ONE 14(4): e0214944. https://doi.org/10.1371/journal.pone.0214944