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Digital and Hands-On Solutions that Meet Your Students’ Needs and Current Science Standards

CAST21

HS-PS3-4 Energy

Students who demonstrate understanding can:

HS-PS3-4. **Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).** [Clarification Statement: Emphasis is on analyzing data from student investigations and using mathematical thinking to describe the energy changes both quantitatively and conceptually. Examples of investigations could include mixing liquids at different initial temperatures or adding objects at different temperatures to water.] [*Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.*]

The performance expectation above was developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices

Planning and Carrying Out Investigations

Planning and carrying out investigations to answer questions or test solutions to problems in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

- Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.

Disciplinary Core Ideas

PS3.B: Conservation of Energy and Energy Transfer

- Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems.
- Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down).

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

Crosscutting Concepts

Systems and System Models

- When investigating or describing a system, the boundaries and initial conditions of the system need to be defined and their inputs and outputs analyzed and described using models.

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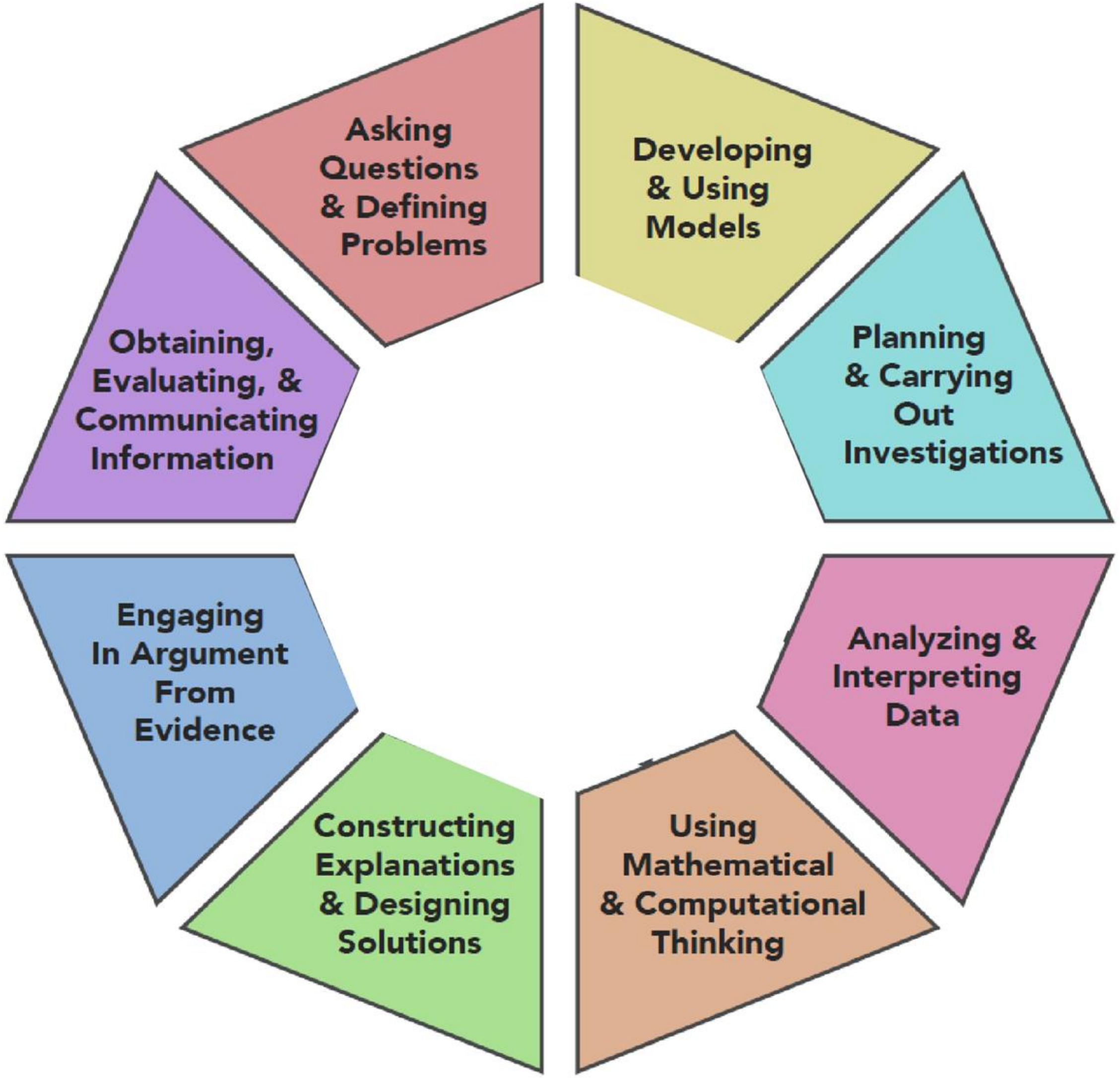
TEKS Examples

112.35. Chemistry (C)(2)(E): Plan and implement investigative procedures, including asking questions, formulating testable hypotheses, and selecting equipment and technology, including graphing calculators, computers and probes, electronic balances, an adequate supply of consumable chemicals, and sufficient scientific glassware such as beakers, Erlenmeyer flasks, pipettes, graduated cylinders, volumetric flasks, and burettes.

112.35. Chemistry (C)(7)(B): The student knows how atoms form ionic, covalent, and metallic bonds. The student is expected to write the chemical formulas of ionic compounds containing representative elements, transition metals and common polyatomic ions, covalent compounds, and acids and bases.

SEPs



Schwarz, C. V., Passmore, C. M., & Reiser, B. J. (2017). Moving beyond "knowing" science to making sense of the world. In C. V. Schwarz, C. M. Passmore & B. J. Reiser (Eds.), *Helping students make sense of the world through next generation science and engineering practices* (pp. 3-21). Arlington, VA: NSTA Press.

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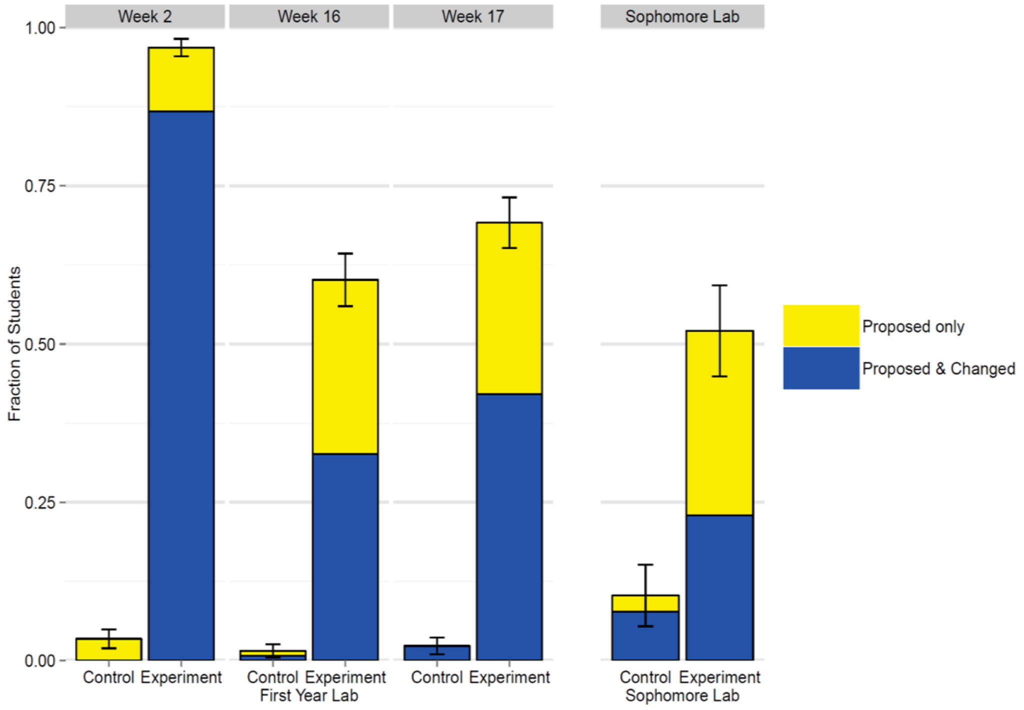
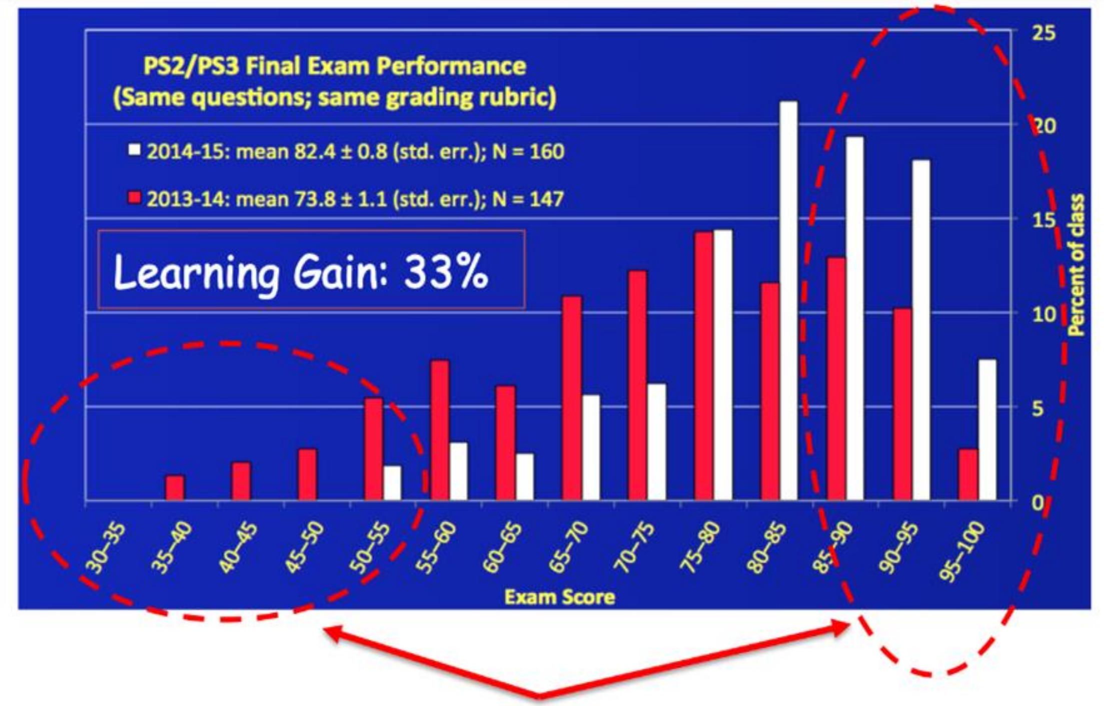
"Developers need to recognize that **most traditional approaches to curriculum materials,** in which teachers or expository texts present new ideas first, and then students apply them in labs or exercises, **do not reflect the three dimensions of NGSS**, in which students engage in **science and engineering practices** to develop and use the **disciplinary core ideas** with guidance from teachers."

Guide to Implementing the Next Generation Science Standards, 2018, National Academy of Sciences

Active *vs* Passive Learning

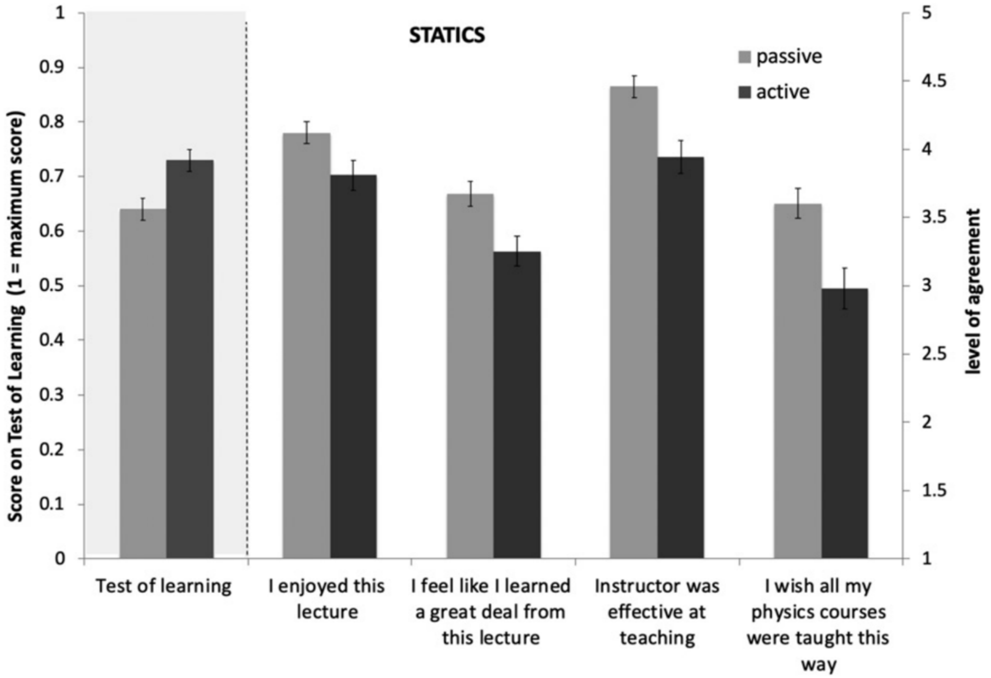


Holmes, N.G. et. al. "Teaching Critical Thinking" *PNAS* 112(36), **2015**, 111999-11204.



Deslauriers, L. et. al. "Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom" *PNAS* 116(36), **2019**, 19251-19257.

Challenge: *Learning More* but *Feeling* Like Learning Less



- Cognitive fluency misleads students
- Novices are ill-equipped to judge how much they have learned
- Students are unfamiliar with intense active learning

Deslauriers, L. et. al. “Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom” *PNAS* 116(36), **2019**, 19251-19257.

How to create a successful and active classroom/lab?

- Improve student perceptions of their learning
- Provide supports to increase feelings of fluency
- Connect learning to meaningful things, i.e. phenomena
- Assess students' abilities to practice science as well as master disciplinary core ideas
- Present information on the benefits of active learning

Impediments

- Time
- Range of student readiness
- Students are not used to this kind of learning, it frustrates

Connect to Students' Interests – Phenomena

Which dyes can be added to food?

What’s the molecular structure of food dyes?

How do dye molecules interact with food?

Intermolecular forces?

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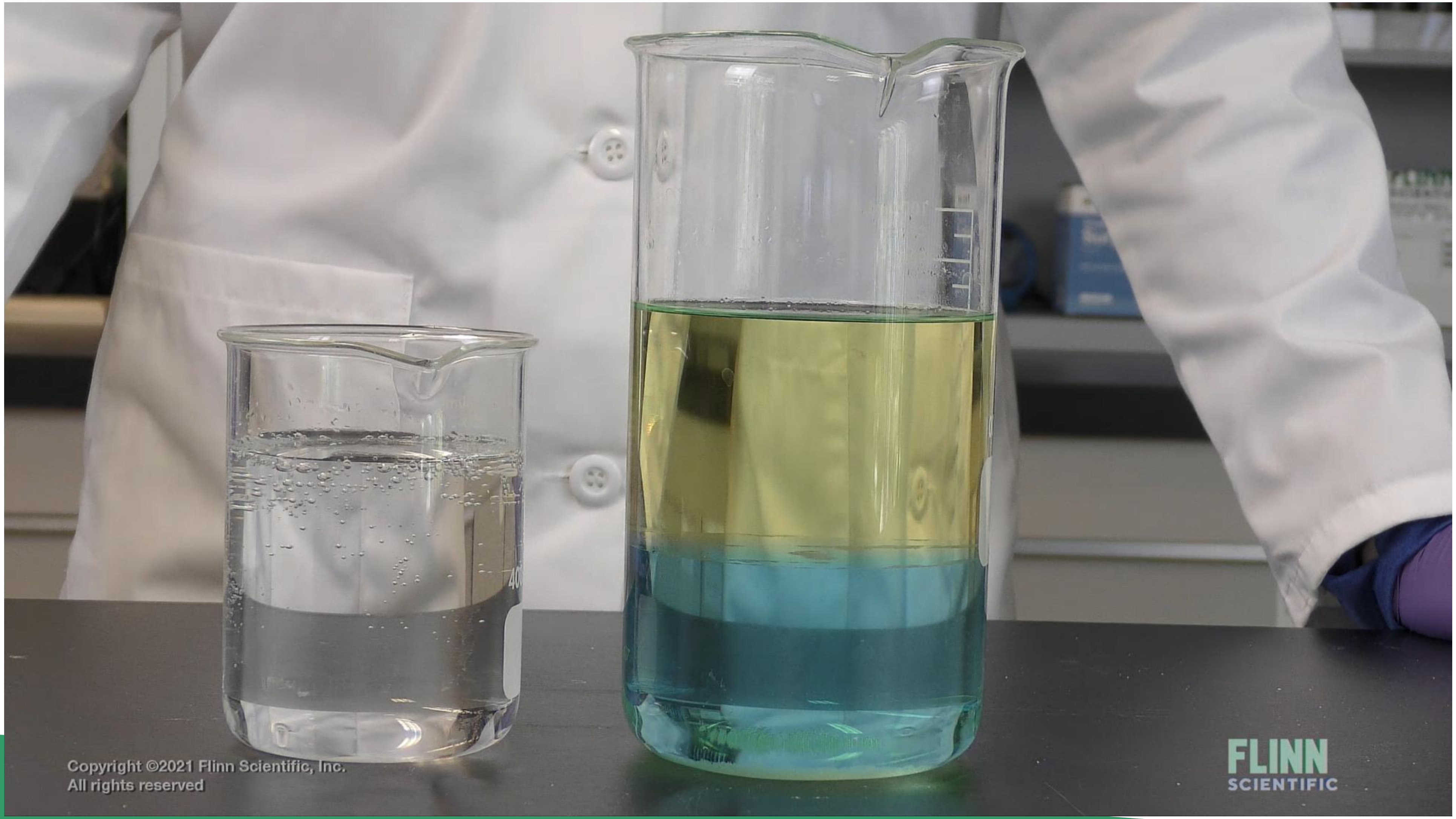
Connect to Students' Interests – Phenomena

HS-PS1-3: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

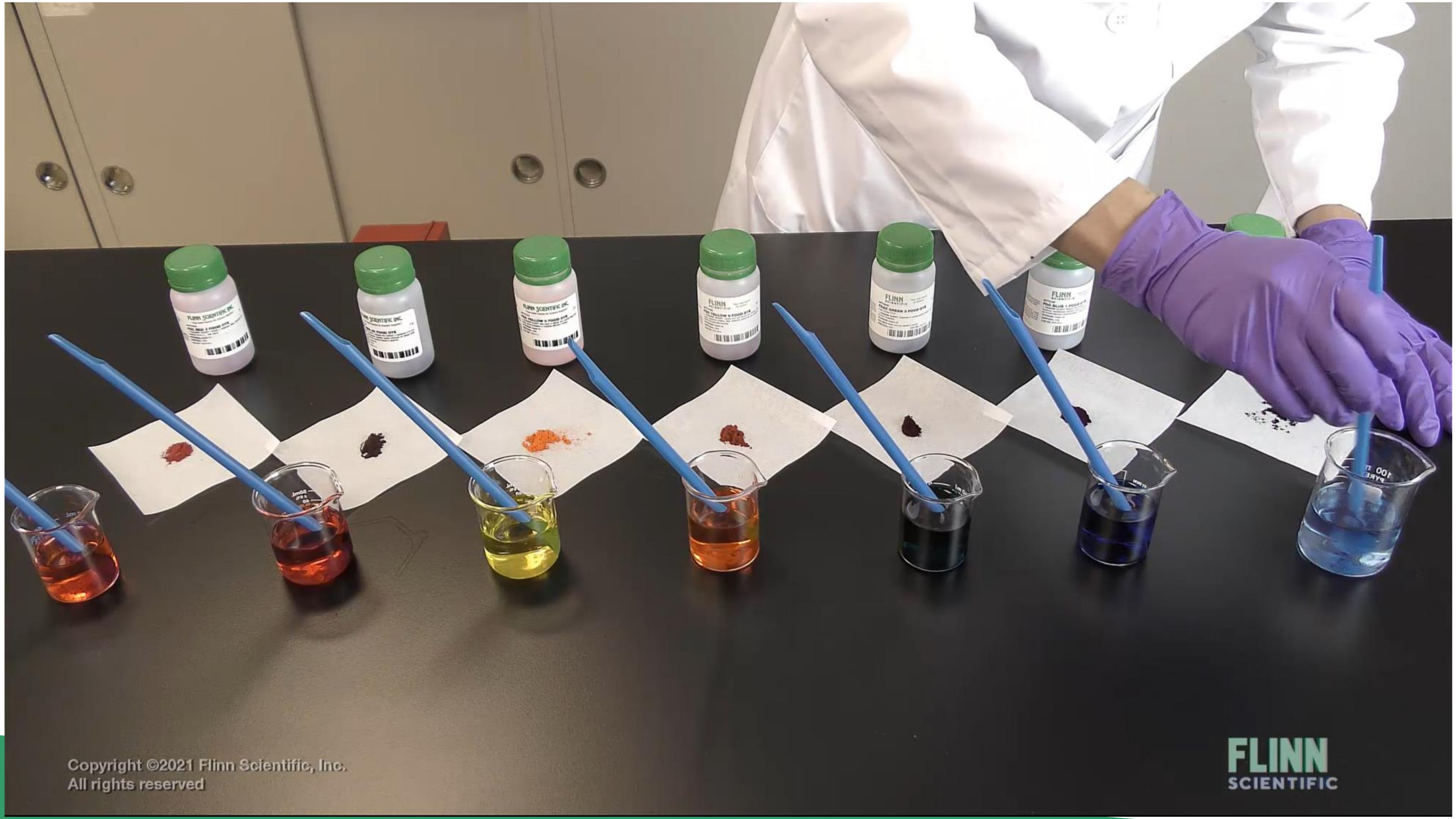
HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Food Coloring → **Colorful Salting Out Demonstration** → **Science2Go: Structure Property Relationships** → **360Science™: Chromatography of a Dye Mixture**

Demonstrations to Spark Interest and Discussion

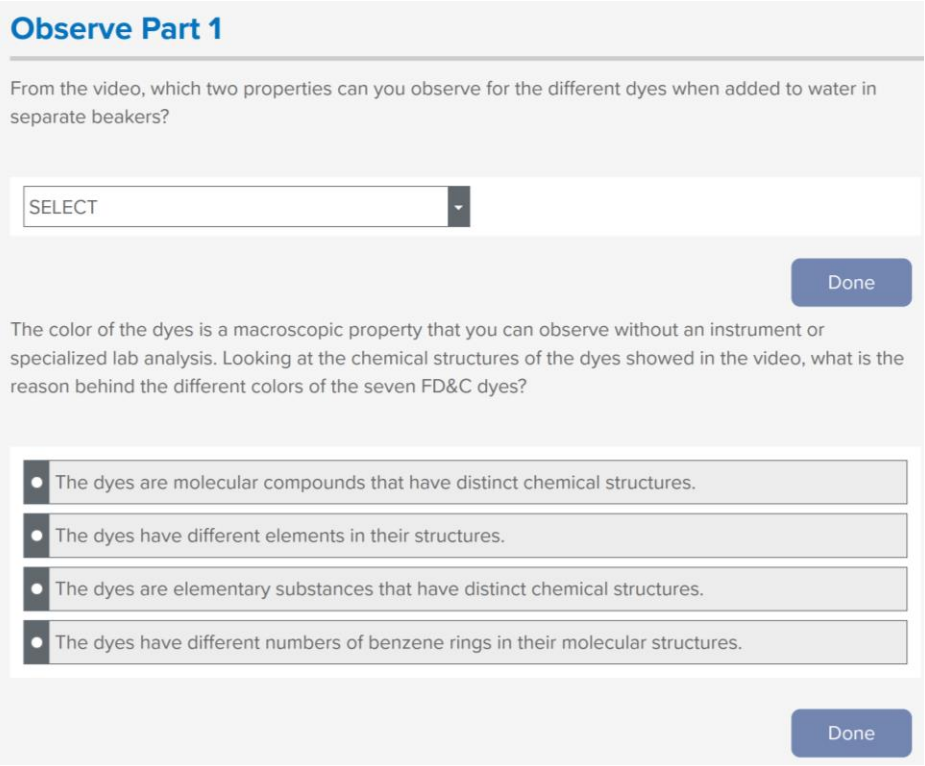


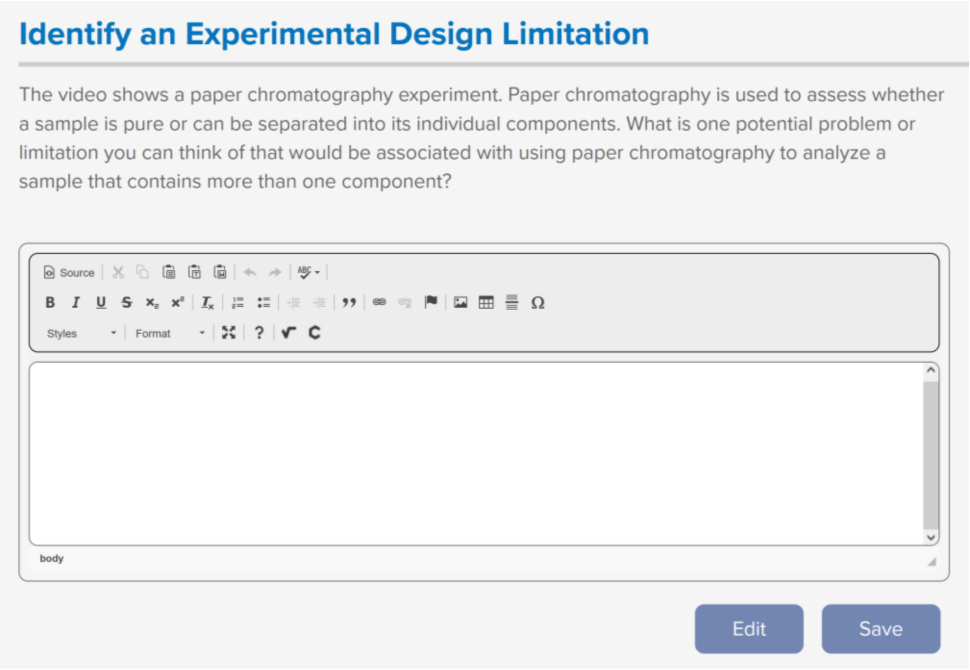
Students Can Practice Science Outside of School



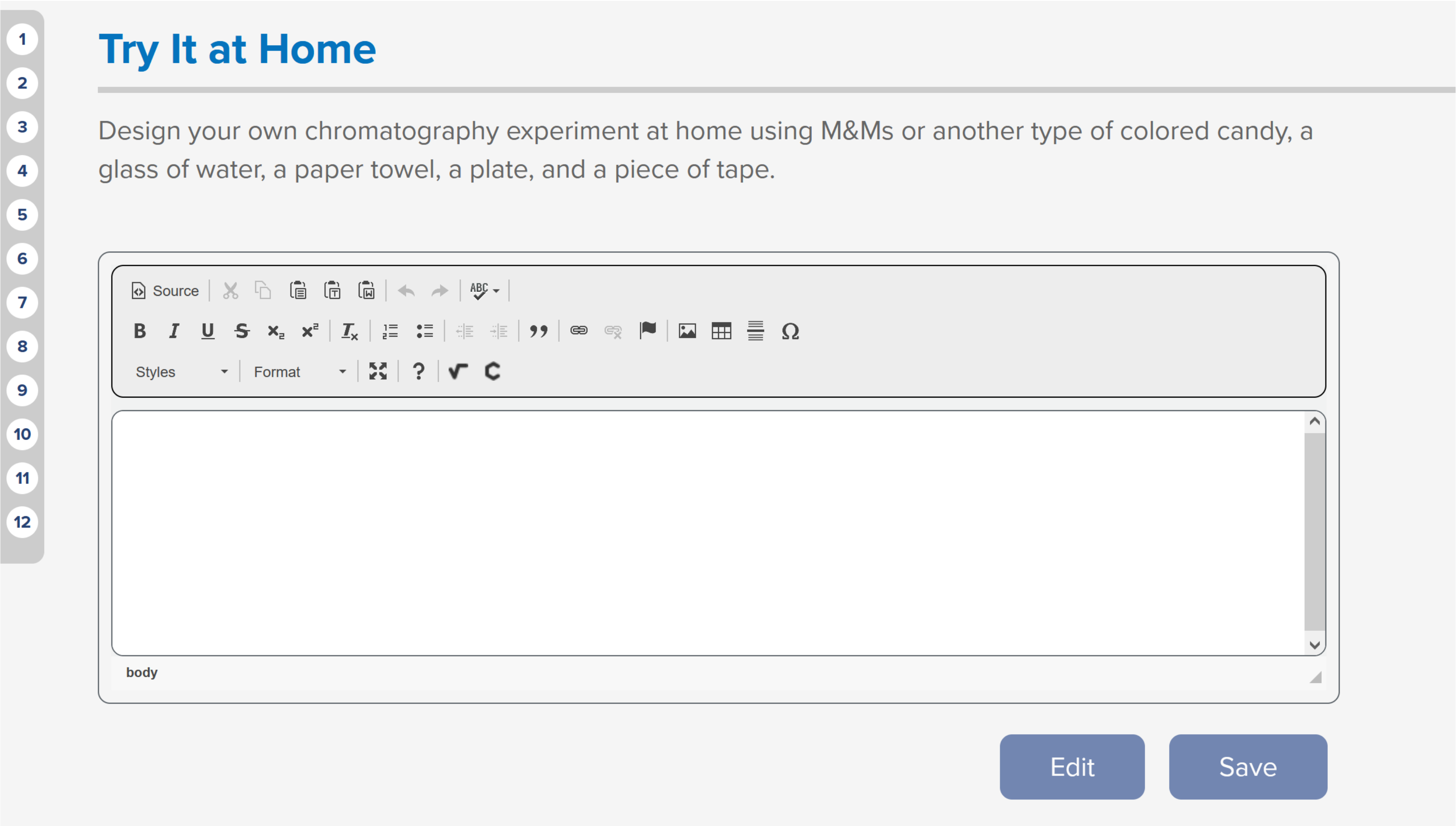
Blur the Line Between In-School and At-Home Science

- Pair videos with prompts meant to elicit students’ abilities to engage in the science practices





Have Students Make Observations and Try Safe Demos at Home



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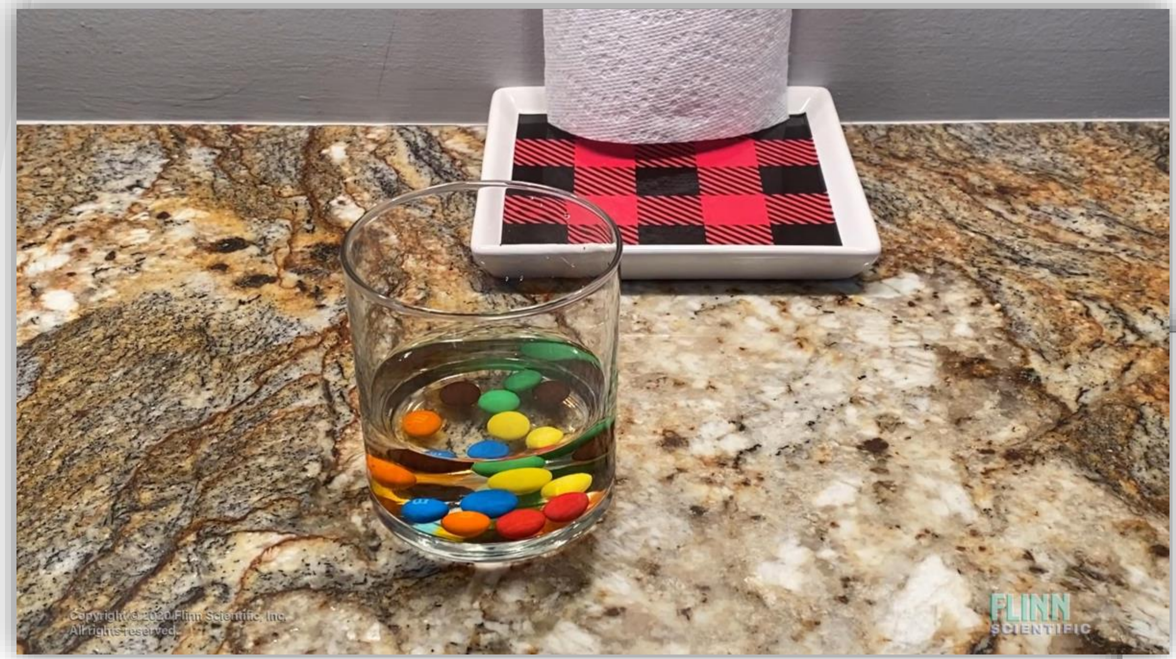

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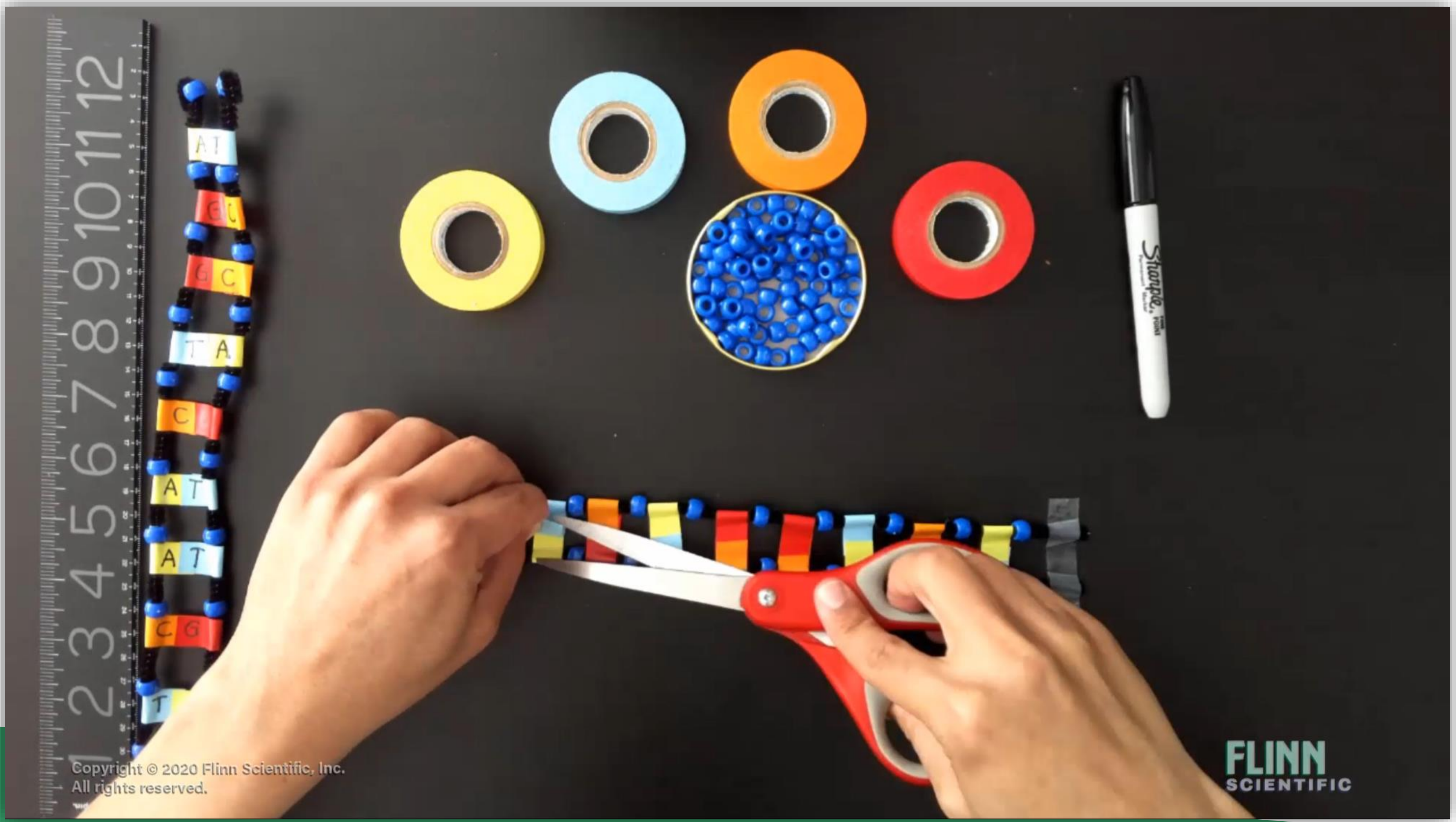

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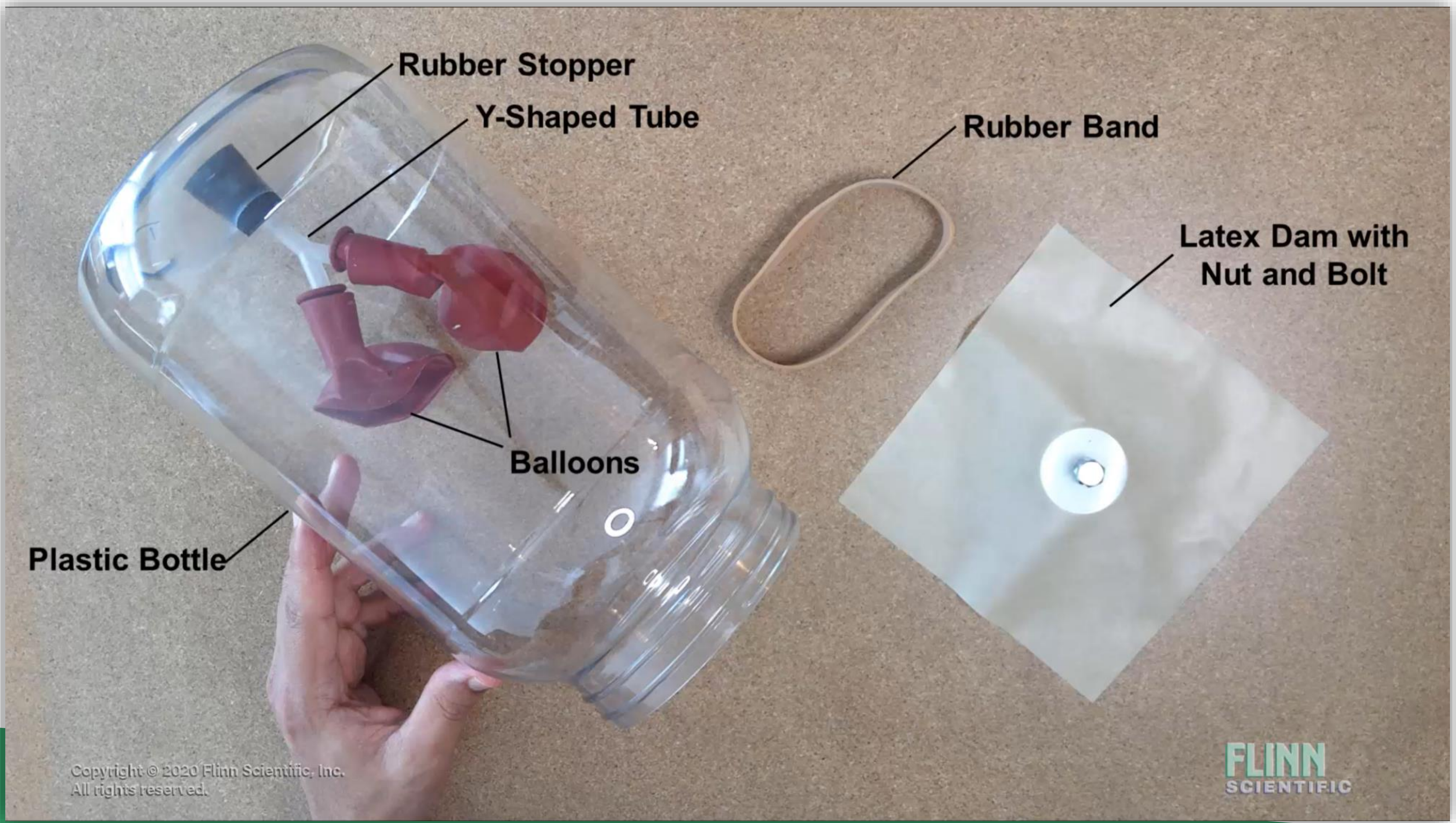
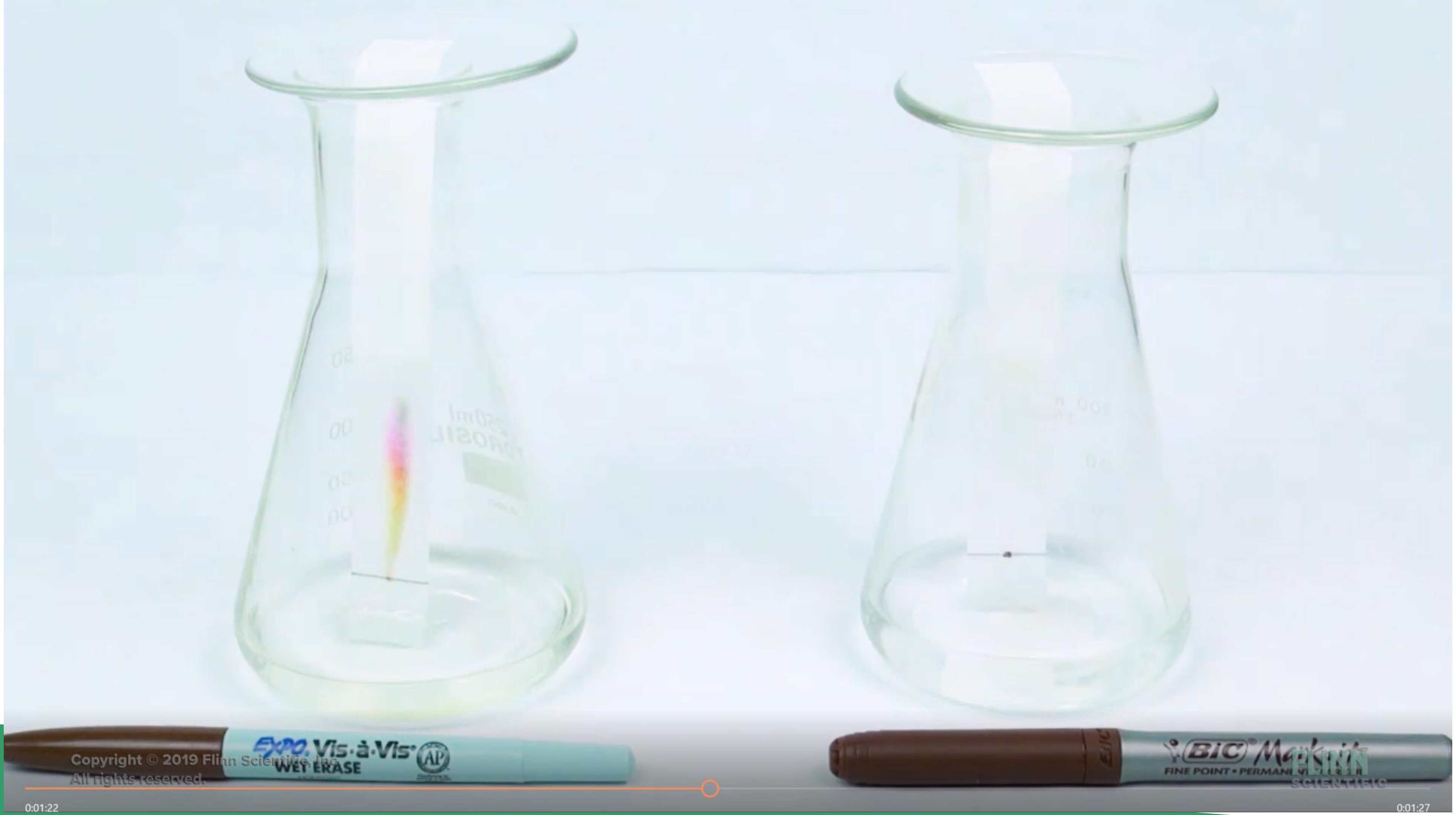


Students Will be Better Prepared for In-School Science



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Activities Must Not Exceed Students' Abilities Early in the Year

Short (Guided) Inquiry

1 2 3 4 5 7

Procedure

Part I. Preparation of Sodium Chloride Solution (Eluent)

1. Use a graduated cylinder to measure 12.5 mL of 2% sodium chloride solution, and transfer to a 100 mL beaker.
2. Use a graduated cylinder to measure 37.5 mL of distilled water, and add it to the beaker containing the 12.5 mL of sodium chloride solution. Mix the solution and label this beaker as "0.5% NaCl."

Part II. Chromatography of a Dye Mixture

3. Position the chromatography paper strip on a clean, flat surface so it is 152 mm long and 19 mm wide. Note: Handle the paper by the edges so the analysis area is not accidentally compacted or contaminated.
4. Using a ruler and a pencil, draw a faint line 15 mm from the bottom of the paper across the width of the strip. Measure 9.5 mm from the edge and place a dot on the line. This is the starting point for the sample.

Open Inquiry

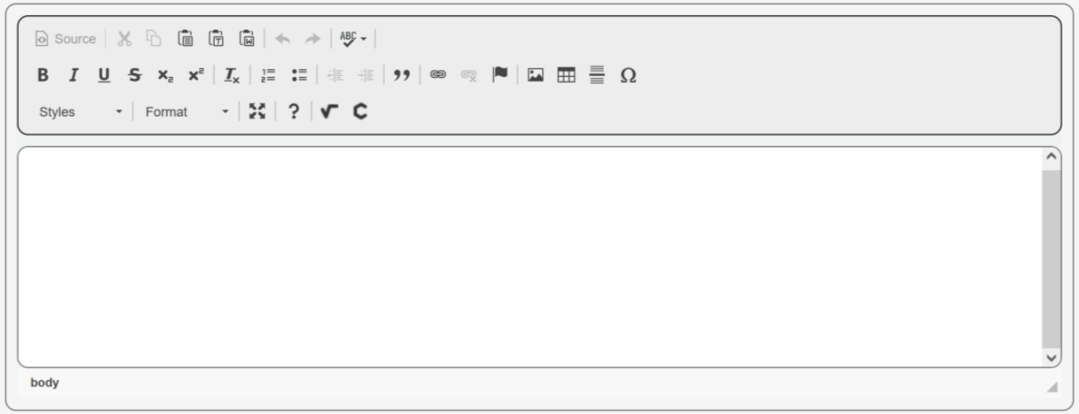
Procedure

Part I. Chromatography Pure Food Dyes

Pick three of the food dyes available to you in this lab. Weigh out approximately 0.1 g of each dye, transfer separately to clean 50 mL beakers, and dissolve the powders in 20 mL of distilled or deionized water. Follow the procedure below to properly conduct the chromatography of these dye solutions. Use a separate paper strip of each dye.

1. Position the chromatography paper strip on a clean, flat surface so it is 152 mm tall and 19 mm wide. Note: Handle the paper by the edges so the analysis area is not accidentally compacted or contaminated.

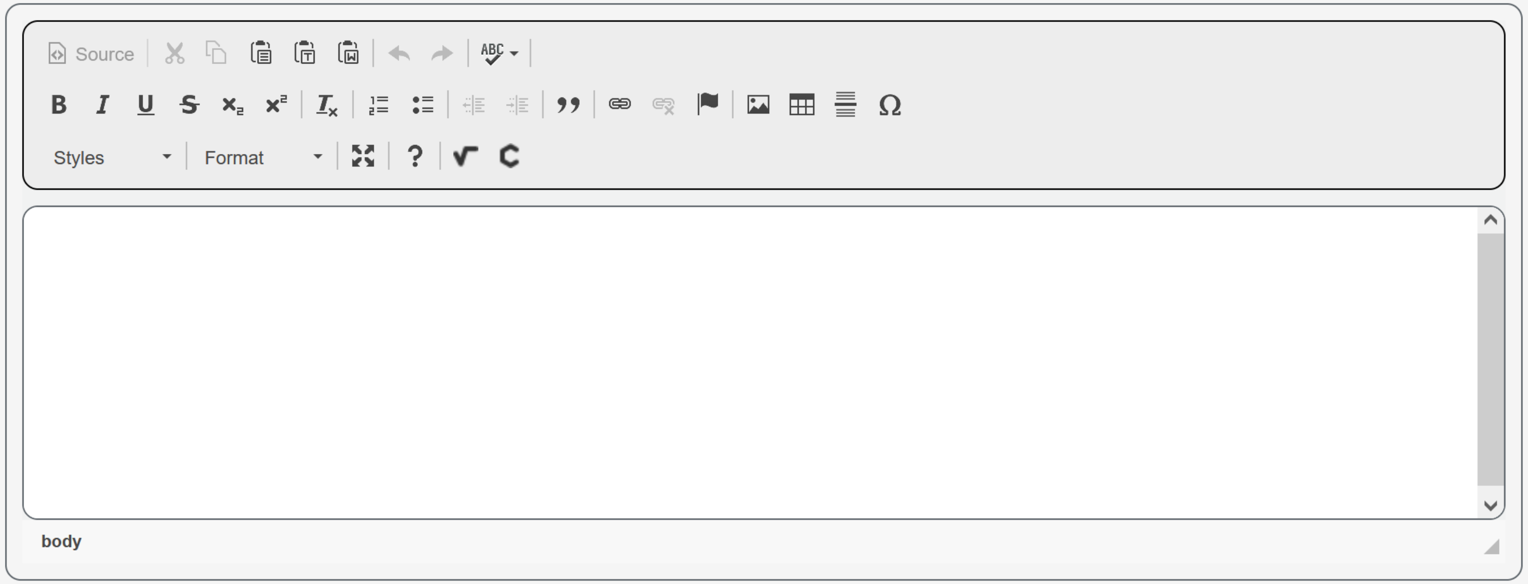
17. **SEP Plan Your Investigation** Design and write a procedure to investigate the effect of concentration of the eluent on the quality of chromatography analysis of your coloring mixture. Prepare and use the two dilutions of stock eluent solution as the developing solvents. Perform two trials with each concentration of eluent if possible. Record your observations (i.e., name and concentration of eluent solution, solvent front distance, distance traveled by each dye on the paper strip) in a data table, and your calculated retention factors (R_f) in a results data table.



Advanced Inquiry

Part II. Effect of Concentration of the Eluent

16. Based on your results from Part I, decide what eluent solution works best for separating the coloring mixture into its component dyes. Determine the amount of stock (2% or 20%) eluent solution required to prepare 50 mL of diluted eluent solutions of different concentrations, which you will use to investigate the effect of eluent concentration of the chromatography of a dye mixture. Show all your calculations.



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Advanced Inquiry

1
2
3
4
5
7

17. Design and write a procedure to investigate the effect of concentration of the eluent on the quality of chromatography analysis of a coloring mixture. Prepare and use the two dilutions of stock eluent solution as the developing solvents. Perform two trials with each concentration of eluent if possible. Record your observations (i.e., name and concentration of eluent solution, solvent front distance, distance traveled by each dye on the paper strip) in a data table, and your calculated retention factors (R_f) in a results data table.

Source

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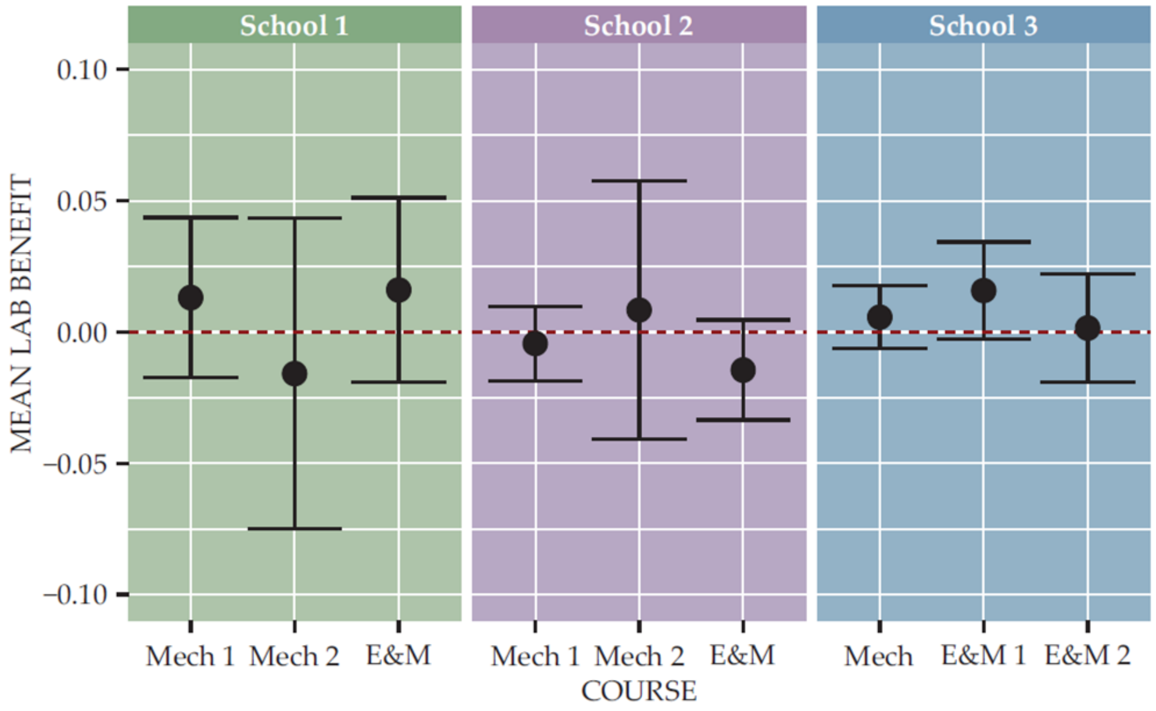
Get Students Comfortable with Less Prescriptive Lab Work



Holmes, N.G. and Weimann, C.E. “Introductory physics labs: We can do better” *Physics Today* 71, 1, 38 (2018)

Pair Videos with Hands-On Activities for Better Outcomes

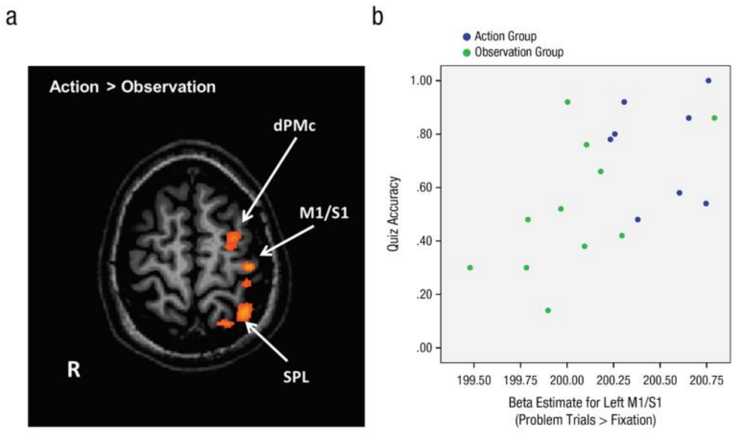


Fig. 4. Imaging results from the posttest in Study 3. The brain image (a), an axial slice at $z = 57$, shows a subset of neural regions in which the activation difference between problem trials and fixation was greater in the action group than in the observation group, for the 19 subjects who completed both the scanning and the online quiz. dPMc = dorsal premotor cortex; M1/S1 = primary motor/somatosensory cortex; SPL = superior parietal lobule; R = right. The scatter plot (b) shows the relation between accuracy on the online quiz and β weight for activation within the left M1/S1 region from the group contrast (problem trials > fixation); each plotted point represents a subject.

Kontra, C. et. al. Physical Experience Enhances Science Learning. *Physiological Science* (2015).

JOURNAL OF CHEMICAL EDUCATION Article

Cite This: *J. Chem. Educ.* 2018, 95, 1260−1266 pubs.acs.org/jchemeduc

Online Prelaboratory Videos Improve Student Performance in the General Chemistry Laboratory

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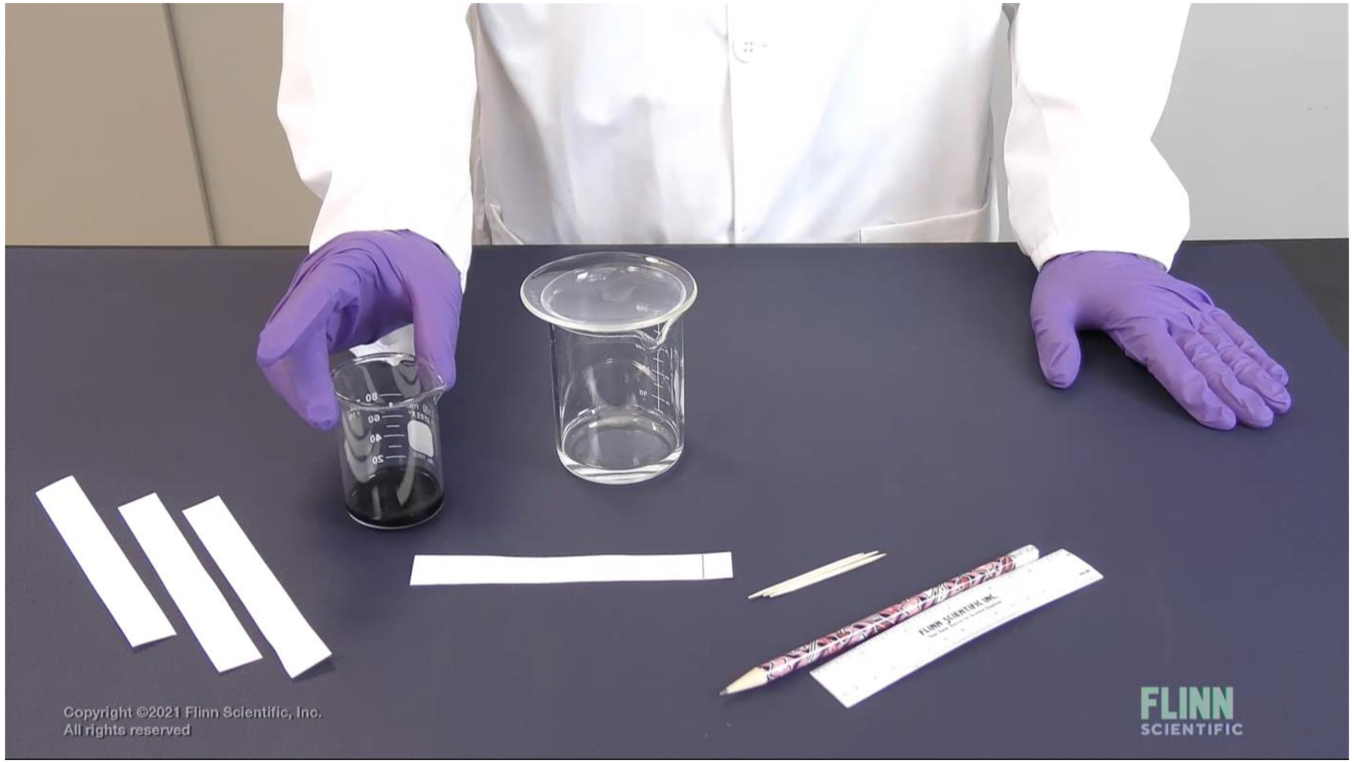
"Students were more efficient and demonstrated a greater understanding of the rationale for the two procedures that used online prelaboratory videos..."

- Analyze videos individually or collectively
- Investigate the questions videos bring up…



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How to Prepare Students

- Benefits of active learning
- Show real data
- Discuss feeling of learning (FOL) *vs* actual learning
- Include a discussion on negative correlation: students in active classrooms feel like they learn less but actually learn more that students in passive classrooms
- Students need time to adjust but once adjusted enjoy active learning much more than passive learning

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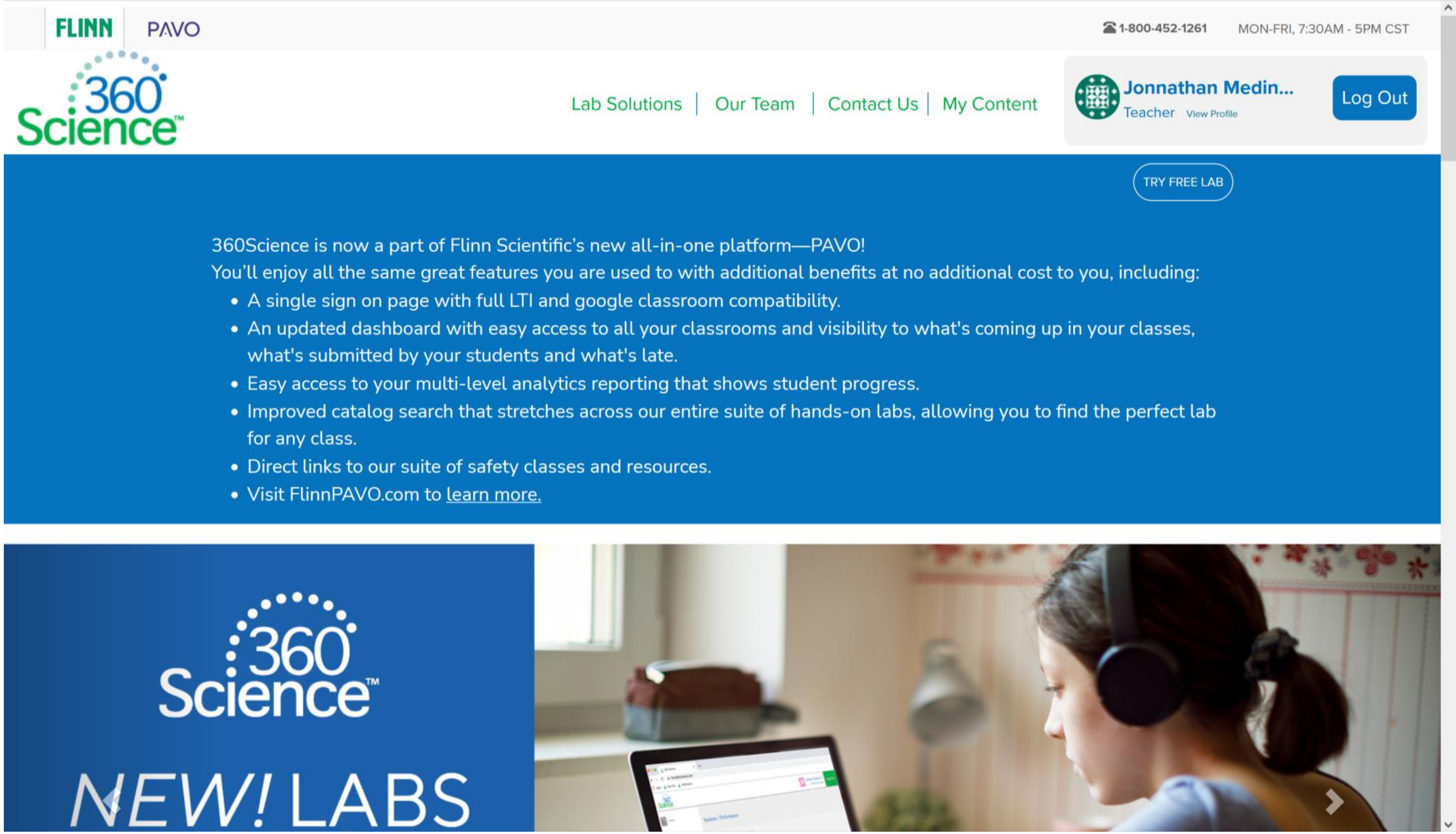

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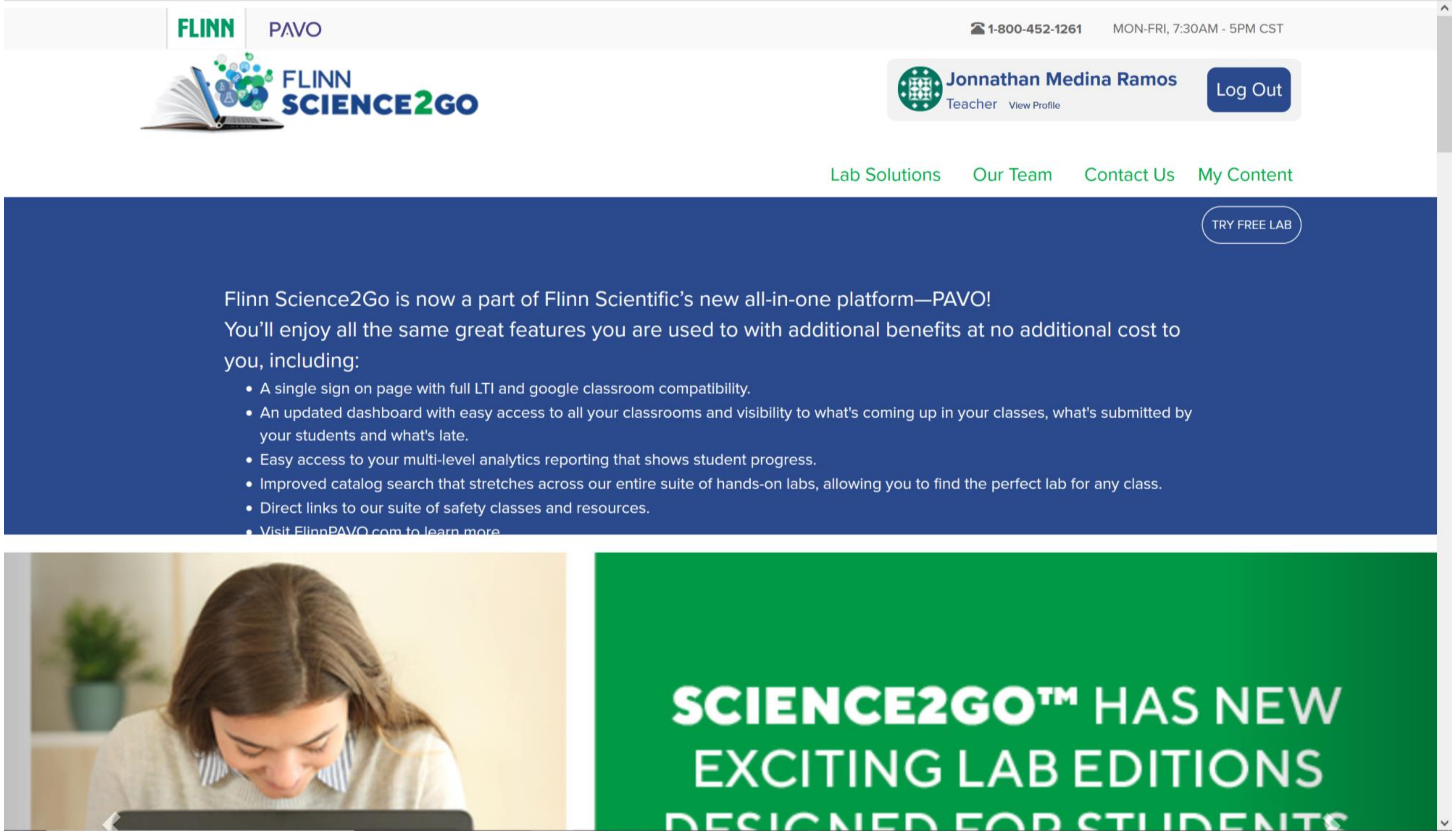

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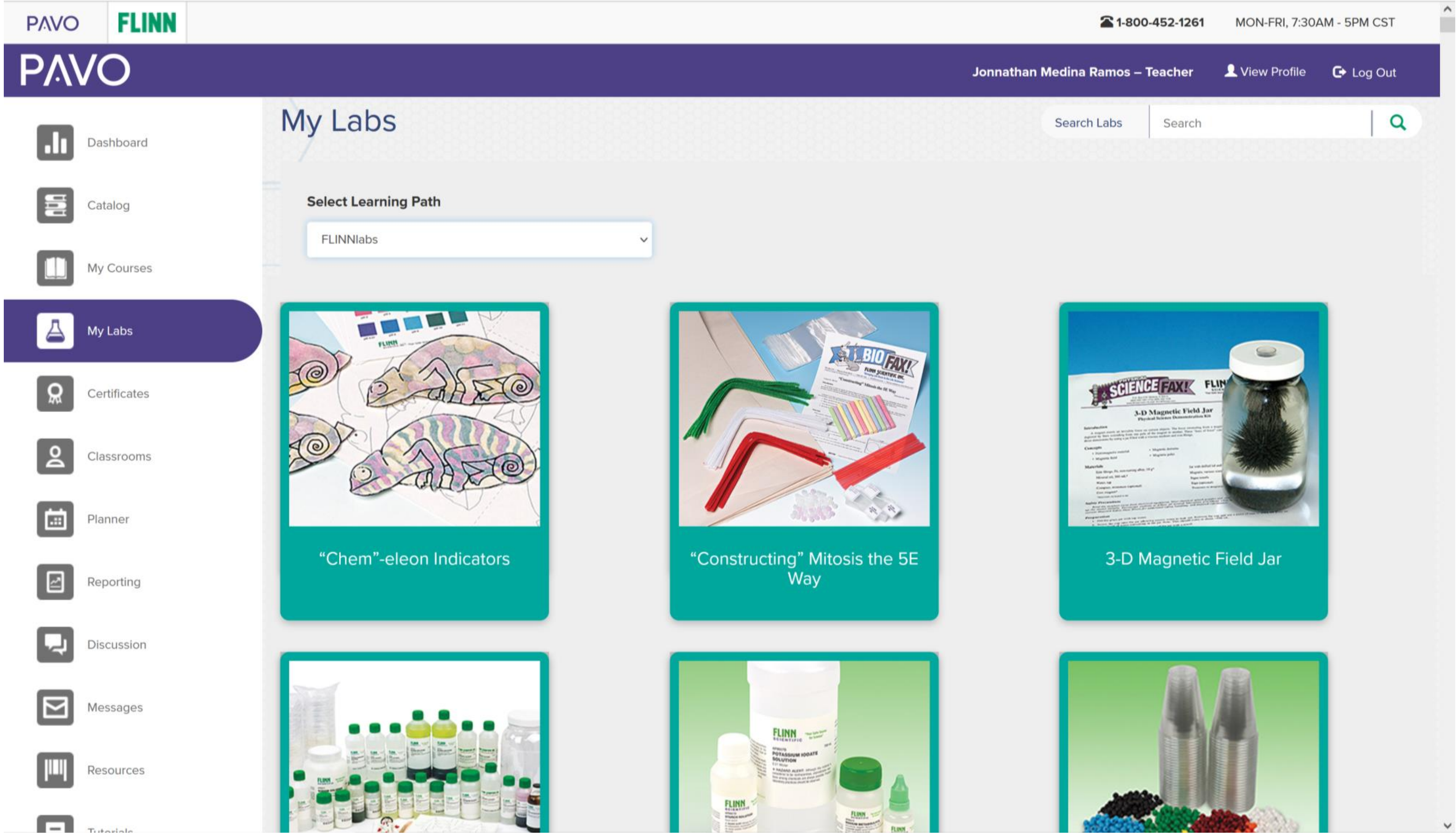

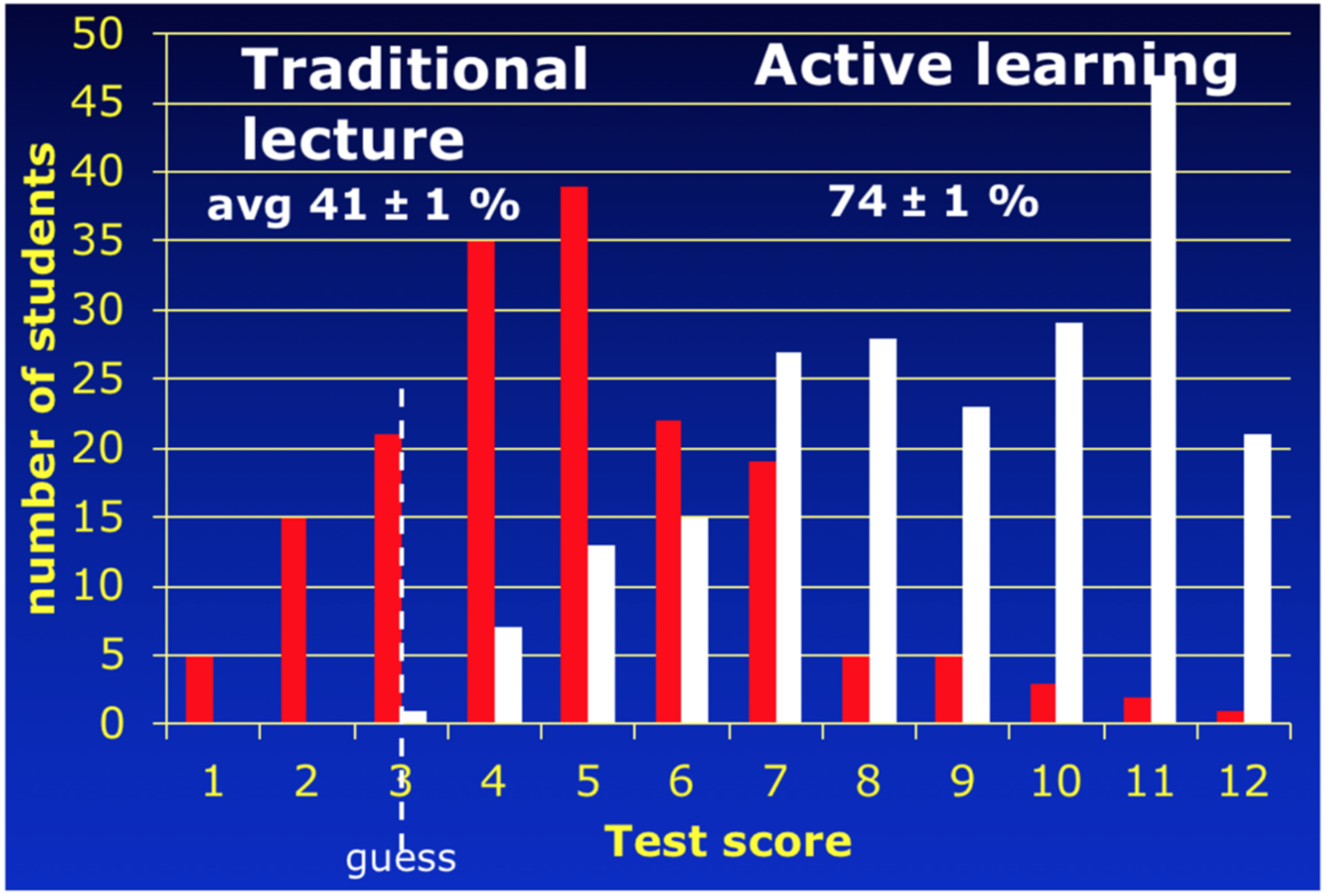

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Why do passive methods persist?

- Insufficient time
- Limited resources
- Lack of support
- Concerns about content coverage
- Concerns about teaching evaluations

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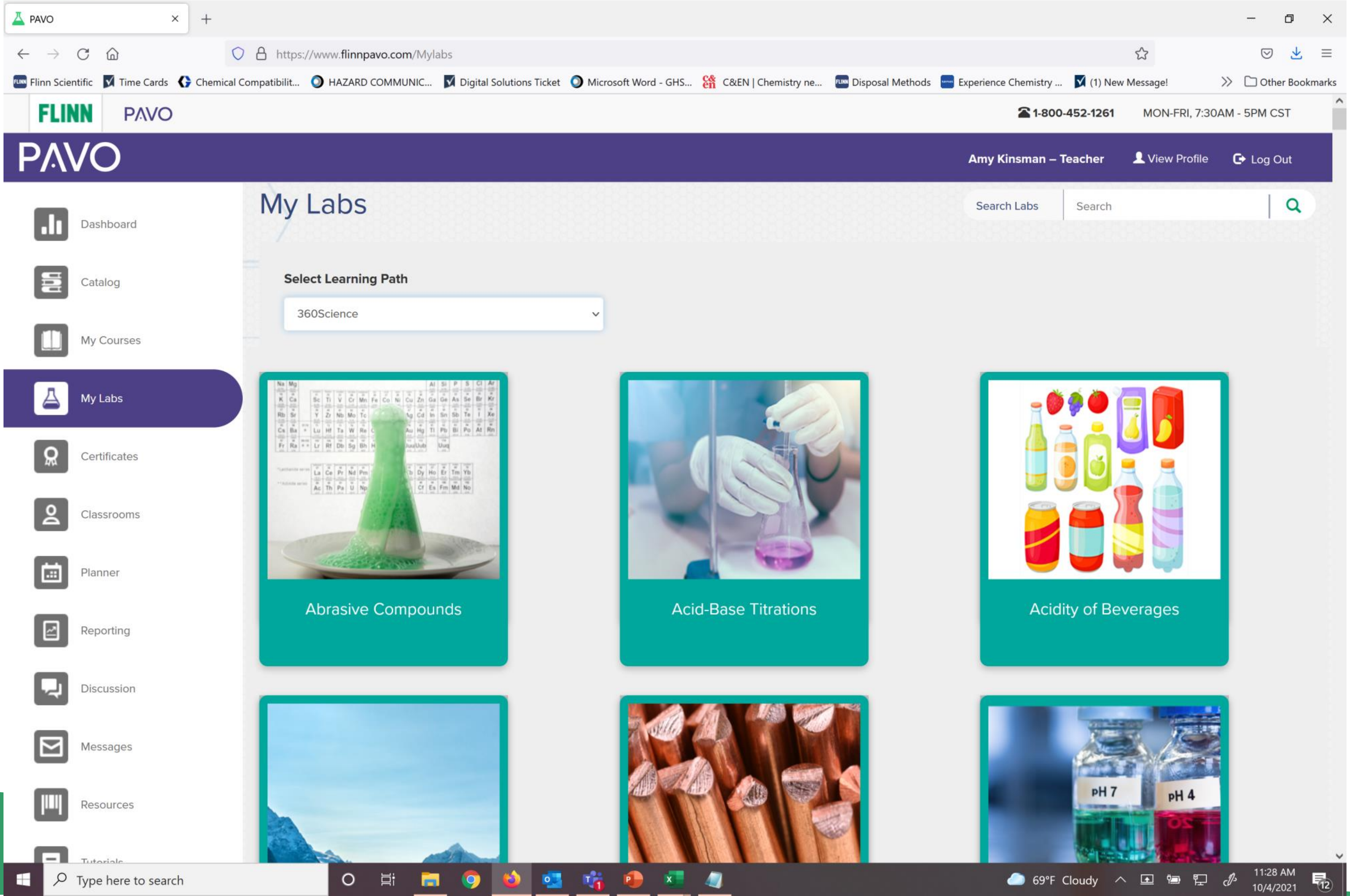

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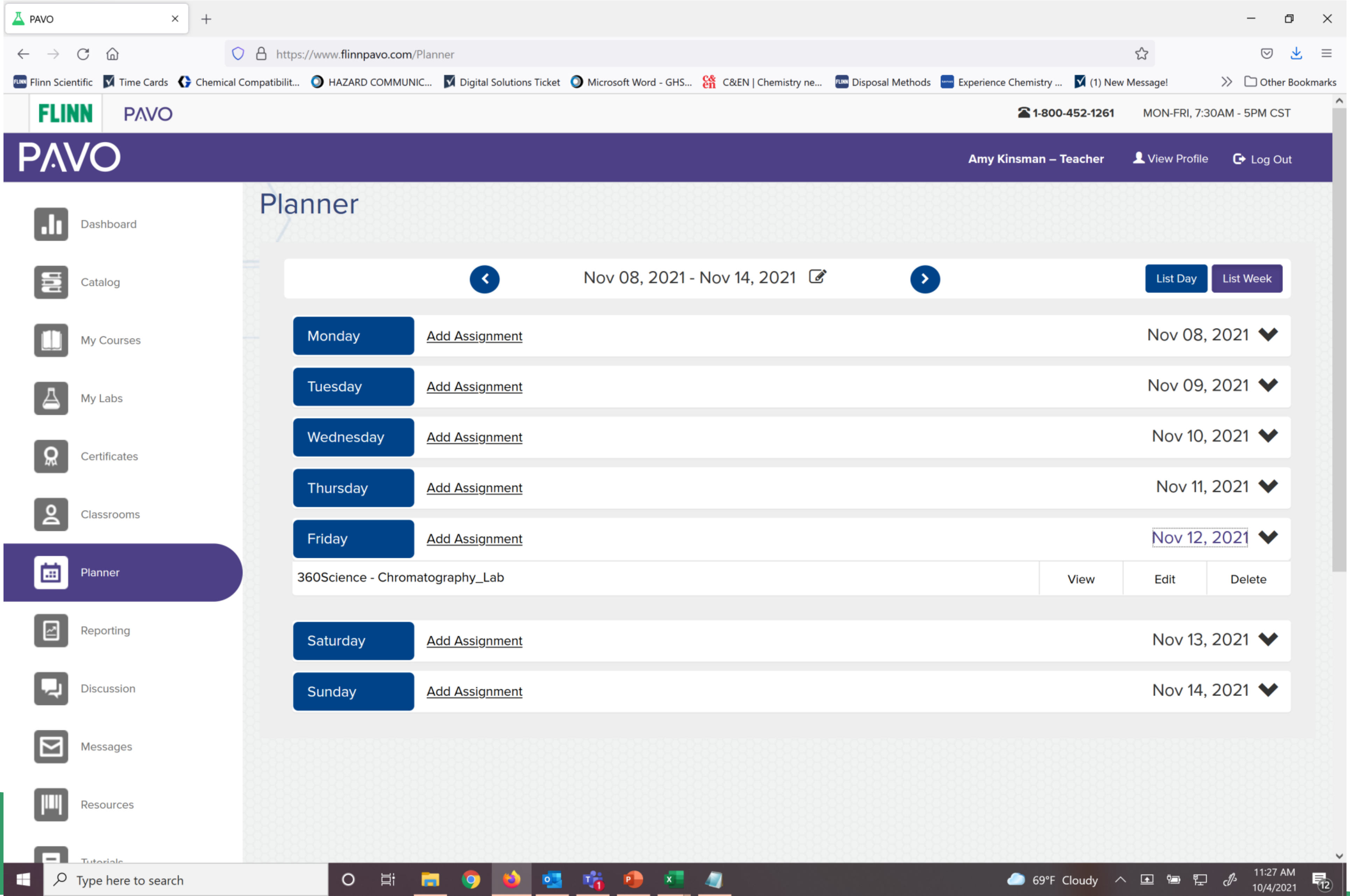

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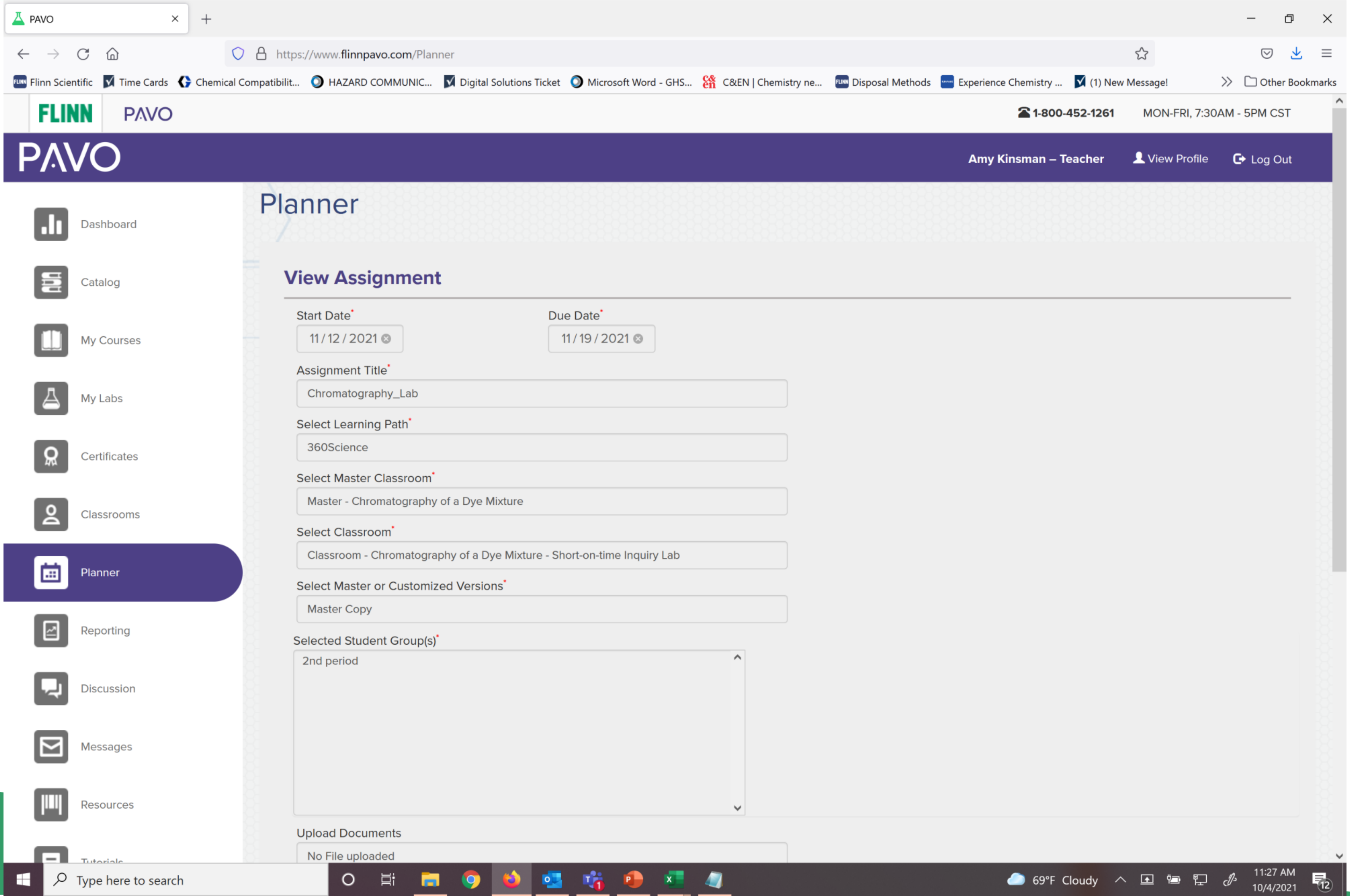

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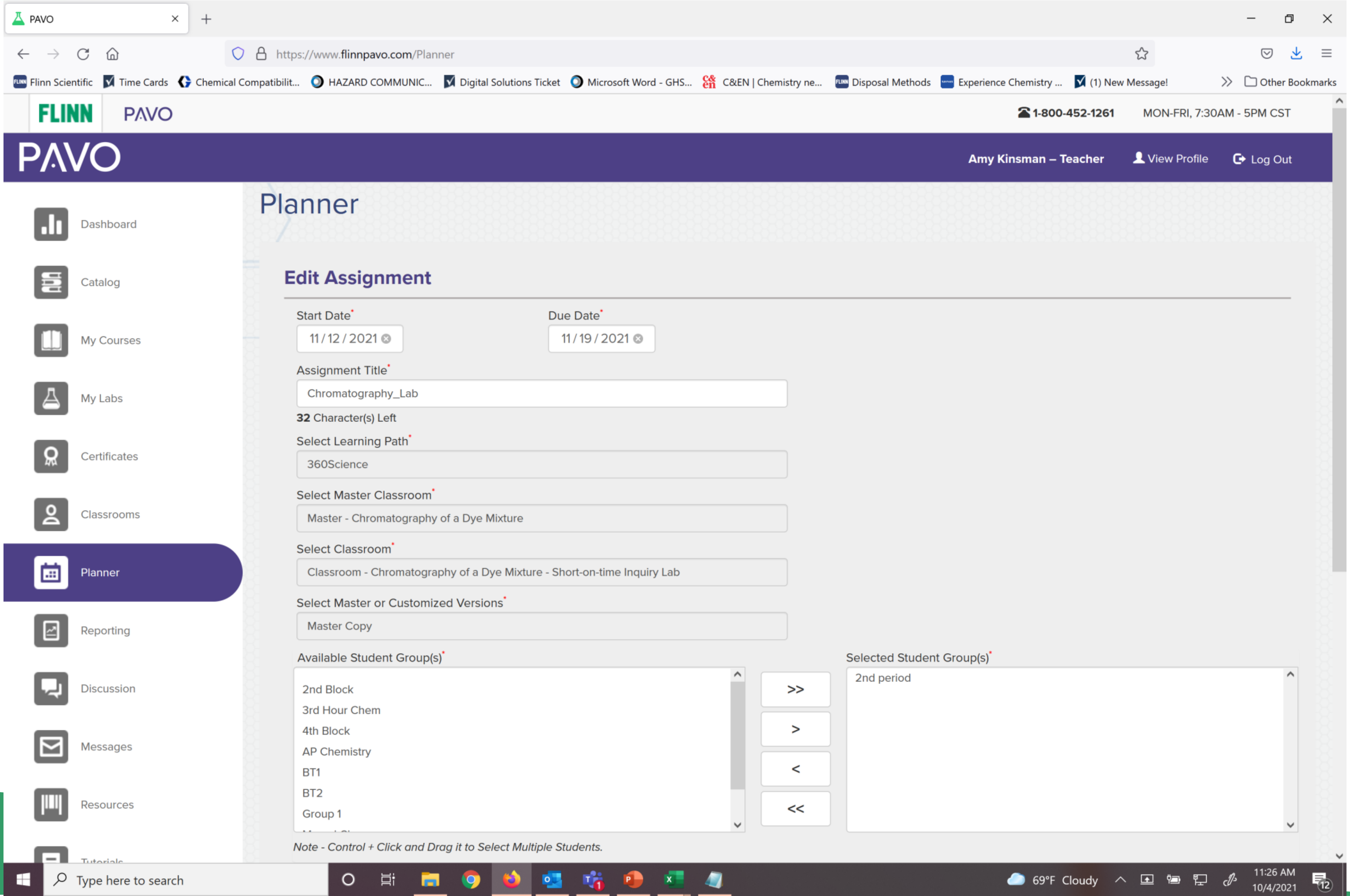

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If you have any questions, give us a call or

send us an email!

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1-800-452-1261

Thank You!