Teaching Certificate Program:
Course Design Project

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Statement of Educational Philosophy

As a professor of higher education, my role is to tailor my teaching to my students' levels when they arrive at college, and then to guide their acquisition of advanced scientific skills over the course of the next several years in anticipation of the skills that will be required in their post-graduate careers. In my introductory classes, this often means helping my students strengthen their algebraic skills (and the confidence associated with them), so that they can rely on a strong mathematical foundation to then develop the critical thinking and problem-solving skills that are needed for chemistry. As students transition to higher-level classes, I expand my instruction from having a central focus on data analysis to a model that then encompasses literature searches, data collection, and data presentation, so that the chemistry students that I have taught enter the work force with a robust set of scientific skills.

In this Course Design Project, I present an upper-level undergraduate course elective that emphasizes this educational philosophy. The intention of the course is twofold:

(1) To provide advanced undergraduates with an interesting and relevant course curriculum once they have completed the basic requirements of the chemistry degree; and

(2) To help advanced undergraduates develop the ability to find and synthesize information from the literature, design and implement research ideas, and effectively communicate scientific ideas both in written and oral formats.

The chemistry core curriculum really only requires two to three years to complete and leaves plenty of time for juniors and seniors to supplement their chemistry education with electives during their final semesters of college. Notably, this provides the opportunity for colleges to shift the focus from disseminating the basics of the chemical sciences to instead making sure that the students they are graduating have the fundamental skills scientists need to have to be successful in the workplace. These skills include not only the quantitative reasoning skills associated with being able to solve specific, individual textbook-type questions, but also the research and communication skills associated with being able to think about and exchange ideas about scientific issues on a larger scale. In my Course Design Project, I present an upper-level undergraduate elective course that gives students an opportunity to develop these skills while learning about a more modern discipline of chemistry—nanochemistry—that will reaffirm and strengthen their fundamental chemical skills in the physical, organic, and inorganic subfields.

Course Description

Chemistry of Nanomaterials:
Synthesis, Characterization, and Applications

This upper-level undergraduate course will provide an overview of the chemistry of nanomaterials with the ultimate goal of relating nanoparticle structure to chemical and physical properties. We will investigate the effects of nanoparticle composition, size, shape, and surface chemistry on nanoparticle properties and learn how to control those parameters using synthetic techniques. We will discuss different methods of nanoparticle characterization, covering microscopy, diffraction, and spectroscopy, and consider how these techniques differ for nanoparticulate vs bulk systems. All of this will be focused on understanding nanoparticle optical, catalytic, and biological properties and placing them in the context of the many rising applications of nanotechnology.

This course will meet two times a week in the classroom and once in the laboratory. The classroom component of the course will feature limited lectures integrated with other classroom activities. As such, students will have short video modules to watch or other readings to complete in preparation for class. In particular, articles from the primary literature will be assigned on a regular basis for discussion in "journal clubs" in class. In the laboratory component of the course, students will synthesize nanomaterials, characterize their properties, and incorporate them into devices to integrate the classroom course material into practical application. Assessments will consist of one midterm and six lab reports.

In addition, this course culminates in a final course project wherein students will have the opportunity to apply their newfound knowledge to design and synthesize a nanoparticle system for a chosen application. The results of this project will be summarized in a written report and presented in a short presentation to their peers.

By the end of this course, students will be able to:

- Identify the influence of the nanoparticle surface, as well as nanoparticle size, shape, and composition, on nanoparticle properties (such as lattice structure and optical bandgap)
- Explain how different synthetic techniques give rise to control over nanoparticle size and shape
- Employ these synthetic techniques in the laboratory to intentionally produce desired types of nanoparticles
- Characterize nanoparticle properties in the laboratory using electron microscopy, x-ray scattering and diffraction, and optical spectroscopy
- Evaluate the performance of a nanoparticle system in the context of a given application
- Integrate concepts that have been presented in the chemical literature to design a nanoparticle system for a chosen application
- Clearly articulate the results of their research (in both written and oral formats)

Inclusive Course Design Strategy

By far one of the most important considerations in my course design is creating an inclusive, learning-centered course. I firmly believe that everybody belongs in science; however, that belief has to be supported by actually welcoming everybody into the classroom, which needs to be supported with actions. The intention to support students of all backgrounds is easily lost when simply focusing on relaying course content, and so below I have outlined my strategies for inclusive course design.

Students often decide whether or not to take a course based off of the syllabus or other course materials that are available online prior to even the first day of class. Lack of an inclusive course design can be readily apparent in these documents, as the structure of classwork, assignments, and assessments impacts inclusivity. To this end, in my class:

- Course expectations will be made explicitly clear in the syllabus. Throughout the semester, I will be consistent in maintaining these expectations and will continue to reference them both in person and in other written documents.
- Course materials will either be free or provided by the instructor/university.
- Review of content that is considered to be a prerequisite for the course will be made available on the course website as it becomes relevant throughout the semester. Students who transferred from other universities, took coursework elsewhere, or feel like they did not properly master prerequisite material should not feel discouraged from selecting this elective.
- Assessments will not be the only component of the final grade, so that students with different skill sets all have the opportunity to succeed and so that no one assignment dominates the course. In this course, students will be asked to submit lab reports, participate in journal clubs, complete literature reviews, and present the results of a research project in both written and oral formats.
- The midterm will be administered during class time (rather than at home or in the evenings, outside of scheduled class time), so that students who have commitments outside of class, such as part-time jobs, are not at a disadvantage.

This inclusive course design must then be followed up by establishing an inclusive course atmosphere on the first day. The lack of familiarity between the students and the instructor is likely to heighten any cultural or other differences that would lead to a non-inclusive environment; thus, it is especially important to be intentional about inclusive course design in the early days of the course. To this end, I will:

- Have students complete a "worksheet" prior to the first day of class that will help introduce themselves to me, both with regards to their personal backgrounds but also their academic interests, so that I can understand their motivations for taking the course.
- Introduce myself on the first day to mirror the assignment they day, emphasizing some of my own personal background. In particular, one aspect of my identity that is not immediately apparent is that I am first-generation American, as my parents immigrated from Russia. This defined my upbringing, and hopefully sharing this information and other details of my background will help students feel comfortable in my classroom.
- Provide an incentive of extra credit for students who introduce themselves to me at my office hours during the first week of classes. I want to make sure it is clear that students can always reach out to me if they need help, and this will help familiarize the concept of attending office hours. Since my office hours may not be convenient for all students, there will also be the option to book a time slot

to meet with me via a web app such as Calendly, which will remain available to students throughout the rest of the semester. Again, the goal is to emphasize that I am available to them.

Throughout the rest of the semester, I will make sure that my interactions with students – and their interactions with one another – contribute to an inclusive environment. I will:

- Choose articles for journal club so that the authors represent a diverse group of scientists, for example in terms of gender and geographic location.
- Use anonymous polling in-class to assess students' understanding and what content needs to be covered more thoroughly.
- Acknowledge any gaps in my knowledge when I am unable to answer a student question. Not only is it important to acknowledge that both instructors and scientists do not know everything, it also highlights that learning is a process that is never finished and is inherently uncomfortable. This discomfort is what drives scientific discovery, though! At an advanced undergraduate level, students should be becoming more familiar with the concept that being a scientist is less about knowing everything and more about being willing to look for the answer when you don't, and it is vital that I demonstrate this practice in my classroom by acknowledging when I do not know something, researching the answer after class, and then following up with students the next day.

Finally, I think it will be important to set up discussions regarding inclusive teaching practices within my department, so that we are brainstorming concrete ways to improve as a department, rather than attempting to address these concerns in isolation. After all, success in science for diverse students via diverse pathways will only be possible if students face equitable pathways to success in all of their classes, rather than just one of them.

Course Schedule

This course is designed on a semester system, which provides 14 weeks of class time. During this period, we will cover all of the topics described in the course description, grouped under four units:

(1) Metal nanoparticles
(2) Semiconductor nanoparticles
(3) Surface structure
(4) Nucleation and growth

This course schedule was designed with the students and the course objectives at the forefront. While most nanoscience courses are designed to simply transfer the maximum amount of nanoscience content as can be allotted into a 10- or 14-week course, I chose to limit the topics to only those that I thought were foundational to the field of nanoscience and therefore covered the objectives outlined in the course description. While it may seem very logical to construct a nanoscience course by sequentially covering the synthesis, characterization, and application of nanoparticles, the specifics of many nanoparticle synthesis techniques are not so important as the overall concepts inherent to nanochemistry. I hope by focusing on less content, but doing so more thoroughly, that my students will come away with a more robust understanding of how molecules and clusters behave on the nanoscale.

Furthermore, I have tried to omit the "characterization" unit by integrating it throughout the course, as I always found it to be a weak point of the course where student and instructor energy falls. Given that examples of electron microscopy, diffraction, and spectroscopy are brought up while discussing nanoparticles throughout the semester, it is worthwhile to integrate these techniques into our discussions of nanochemistry from the start rather than confining the topic to a specific unit. This will also allow for discussion regarding the challenges researchers face when analyzing nanoparticles, given the difficulty of employing these techniques on the nanoscale. Integrating the discussion of synthesis and characterization of nanoparticles will mirror how the students will interact with the chemistry in the laboratory, too, as they will be both synthesizing and characterization nanoparticles each week, rather than only doing synthesis in the first portion of the course and then saving the characterization for one special unit later on.

Week	Session	Topic	Pre-Work	In Class	Deadlines (due at 11:59pm, i.e. after class)
1	A	Introduction to nanoparticles	Student introductions	Background knowledge + misconceptions	
1	B	Metal NPs			
1	Lab	*Lab does not meet in week 1*			
2	A	Metal NPs → Electron microscopy			
2	B	Metal NPs	- Read article(s) for journal club - Complete worksheet to guide your reading	Journal club Journal club - evaluation	
2	Lab	***Plasmonic metal NPs***	- Watch lab technique video - Write out lab procedure		
3	A	Introduction to quantum dots → Optical spectroscopy			
3	B	Semiconductor NCs: Composition, size, and shape			Lab report #1
3	Lab	***Size-dependent properties: CdSe NPs***	- Watch lab technique video - Write out lab procedure		
4	A	Semiconductor NCs: Composition, size, and shape	- Read article(s) for journal club - Complete worksheet to guide your reading	Journal club Journal club - evaluation	
4	B	Semiconductor NCs: Composition, size, and shape → Diffraction			Lab report #2
4	Lab	***Composition, size, and shape-dependent properties: $CsPbX_3$ NCs***	- Watch lab technique video - Write out lab procedure		

5	A	Semiconductor NCs: Composition, size, and shape			Literature review
5	B	Semiconductor NCs: Composition, size, and shape		Mid-term evaluation	Lab report #3
5	Lab	***Quantum dot LEDs***	- Watch lab technique video - Write out lab procedure		
6	A	NP structure and surfaces → Spectroscopy (NMR, IR)			
6	B	NP structure and surfaces	- Read article for journal club - Complete worksheet to guide your reading	Journal club Journal club - evaluation	Lab report #4
6	Lab	***NP surface chemistry***	- Watch lab technique video - Write out lab procedure		
7	A	Nucleation and growth			Literature review
7	B	Nucleation and growth			Lab report #5
7	Lab	***TBD***	- Watch lab technique video - Write out lab procedure		
8	A	Exam review		Groupwork to begin generating test questions	
8	B	Exam review	Finish making test questions		Lab report #6
8	Lab	*No lab in week 8 – however, the lab will be open for use*			
9	A	N/A		Midterm Post-exam, mid-term evaluation	
9	B	N/A	- Read article(s) for journal club - Complete worksheet to guide your reading	Journal club Journal club - evaluation	Synthesis and characterization plan
9	Lab	**Independent projects**			

10	A				
10	B				
10	Lab	**Independent projects**			
11	A				Project progress report
11	B			Peer review of progress reports	
11	Lab	**Independent projects**			
12	A		- Read articles for journal club	Journal club Journal club - evaluation	
12	B		- Read articles for journal club	Journal club Journal club - evaluation	
12	Lab	**Independent projects**			
13	A				
13	B				Project final report
13	Lab	*Lab does not meet in week 13*			
14	A			Presentations	
14	B			Presentations End-of-term evaluation	
14	Lab	*Lab does not meet in week 14*			

Assessment and Evaluation Plan

Overview

Week	Assignment	Formative vs Summative	Assessment vs Evaluation
1	Background knowledge + misconceptions	Formative	Assessment
2	Journal club	Formative	Assessment
2	Journal club – evaluation	Formative	Assessment
3	*Due:* Lab report	Formative	Assessment
4	Journal club	Formative	Assessment
4	Journal club – evaluation	Formative	Assessment
4	*Due:* Lab report	Formative	Assessment
5	*Due:* Literature review	Formative	Assessment
5	*Due:* Lab report	Formative	Assessment
5	Mid-term evaluation	Formative	Evaluation
6	Journal club	Formative	Assessment
6	Journal club – evaluation	Formative	Assessment
6	*Due:* Lab report	Formative	Assessment
7	*Due:* Literature review	Formative	Assessment
7	*Due:* Lab report	Formative	Assessment
8	*Due:* Lab report	Formative	Assessment
8	*Due:* Student-generated test questions	Summative	Assessment
9	Midterm	Summative	Assessment
9	Post-exam, mid-term evaluation	Formative	Evaluation
9	Journal club	Formative	Assessment
9	Journal club – evaluation	Formative	Assessment
9	*Due:* Synthesis and characterization plan	Formative	Assessment
10	-		
11	*Due:* Project progress report	Formative	Assessment
11	Peer review of progress reports	Formative	Assessment
12	Journal club (×2)	Formative	Assessment
12	Journal club – evaluation (×2)	Formative	Assessment
13	*Due:* Project final report	Summative	Assessment
14	Presentations	Summative	Assessment
14	End-of-term evaluation	Formative	Evaluation

Grading breakdown

Assignment	Percentage
Lab reports	30 %
Journal clubs (participation)	15 %
Literature reviews	10 %
Midterm	15 %
Final project – written reports	17 %
Final project – oral presentation	6.5 %
Final project – other components	6.5 %

Assessments

Background knowledge probe/misconception check – week 1

This (pre)formative assessment will be used to help me gauge students' incoming knowledge in the area of nanochemistry. It will also serve to check their misconceptions in the field of nanotechnology, especially pertaining to any associated dangers related to health or safety.

Lab reports – weeks 3-8

As this is predominantly a laboratory course that will have a laboratory section that meets once a week, students will have lab reports to turn in each week following the experiments they completed in lab the prior week. The formats of these may vary depending on how much is going on in the rest of the course, but the goal is to improve their communication and research presentation skills in anticipation of the final project that they complete in the second half of the course. The discussion sections of these lab reports will also allow them to apply course knowledge to explain their results.

Connected objectives:

- Identify the influence of the nanoparticle surface, as well as nanoparticle size, shape, and composition, on nanoparticle properties (such as lattice structure and optical bandgap)
- Explain how different synthetic techniques give rise to control over nanoparticle size and shape
- Clearly articulate the results of their research (in both written and oral formats)

Journal clubs – weeks 2, 4, 6, 9, 12

In journal club, students will have a supportive environment in which to analyze one or two papers as a class. Students will have read the paper(s) for homework; the following day in class, we will have a structured discussion regarding the paper's main findings. The goal is to help students learn how to read papers and overcome the difficulty that many undergraduate students initially face when reading the literature. This will be vital for their final project later in the course, where they will have to come up with a project idea based on research that has been reported in the chemical literature.

Journal clubs will evolve throughout the semester to become more independent. While they will initially be led by the instructor, we will later shift to a model in which students act as discussion leaders. The goal is for students to become comfortable verbally articulating and discussing research results. During the final weeks of the course, when students are working on their final projects, every student will have the chance to be a discussion leader and lead a journal club based on an article of their choice—likely one they have come across already when researching their projects.

After each journal club, students will submit a self-evaluation to assess their participation in the journal club discussion and their understanding of the article. The evaluation will also provide an opportunity for me to evaluate if the paper was interesting, too difficult/easy to understand, etc., in order to determine if the paper was an appropriate selection for the class.

Connected objectives:

- Integrate concepts that have been presented in the chemical literature to design a nanoparticle system for a chosen application
- Clearly articulate the results of their research (in both written and oral formats)

Literature review – weeks 5, 7

Literature reviews will be homework assignments in which students will be asked to select a topic (of their choice, though suggestions will be provided) and then find and summarize a few references from the chemical literature on the topic. If desired, the second literature review can be used to start planning for the final project.

Connected objectives:

- Integrate concepts that have been presented in the chemical literature to design a nanoparticle system for a chosen application

Student-generated test questions – week 8

Midterm – week 9

Prior to the midterm, students will be asked to generate their own set of test questions to prepare for the exam. They will begin this assignment in class in groups and then will be finish it for homework, either collaboratively or independently depending on student preference. This will help them assess the most important concepts covered in the course and jumpstart their studying.

The midterm itself will have two parts. There will be in-class component that consists of multiple choice and short answer questions that will be able to assess students' learning of the more basic concepts. Then, there will also be a couple of long answer questions assigned as a take-home exam (more like homework) that will require students to read a paper and answer questions about the chemical concepts presented in that paper. I think it's important to give students enough time to sift through their thoughts; timed situations are not really replicated in professional settings, so there is no need for them in school, other than convenience.

Connected objectives:

- Identify the influence of the nanoparticle surface, as well as nanoparticle size, shape, and composition, on nanoparticle properties (such as lattice structure and optical bandgap)

- Explain how different synthetic techniques give rise to control over nanoparticle size and shape
- Characterize nanoparticle properties in the laboratory using electron microscopy, x-ray scattering and diffraction, and optical spectroscopy

Synthesis and characterization plan – week 9

Project progress report – week 11

Peer review of progress reports – week 11

Project final report – week 13

Project presentation – week 14

The material presented in the first part of the course is ultimately put to use in the final project, where students will have the opportunity to choose a type of nanoparticle application and then design a nanoparticle system with that application in mind. The final project will be broken down into multiple stages in order to provide students with feedback and support throughout the entire process.

First, students will submit a synthesis and characterization plan indicating their plans for the project. Then, a report on their initial progress (similar to a lab report) will be due after the first two weeks so that they can receive feedback on their work before turning in a final written report for the end of the course. The intermediate progress report will be peer reviewed, both so that students can receive some feedback, and so that students receive a chance to practice delivering effective feedback. Finally, students will present their research in an oral format to their peers.

Connected objectives:

- Employ synthetic techniques in the laboratory to intentionally produce desired types of nanoparticles
- Characterize nanoparticle properties in the laboratory using electron microscopy, x-ray scattering and diffraction, and optical spectroscopy
- Integrate concepts that have been presented in the chemical literature to design a nanoparticle system for a chosen application
- Clearly articulate the results of research, in both written and oral formats

Evaluations

Mid-term evaluation – week 5

After a few weeks, I plan to administer an evaluation of the course to ascertain how students are feeling about the course set-up. I believe this will be especially important in the first year of the course, where I will likely need to adapt the course design in response to student feedback. In particular, I will be interested in noting how students respond to the journal clubs; the format of this classroom activity can easily be modified going forward in the semester if my initial format is not effective in meeting my learning objectives. Similarly, it will be critical to make sure that students are receptive to the first few lab activities, as the course is primarily structured around lab experiments and using those in-person activities to reinforce the concepts introduced in class.

Post-exam, mid-term evaluation – week 9

At this point in the course, we will have finished learning all of the course content and done all of the lab experiments. It will therefore be an appropriate point to evaluate the course before embarking on the final project.

End-of-term evaluation – week 14

At the end of the course, I will once again ask students for feedback, now that they will have gone through the entire course sequence.

Lesson Plan

Topic and Context

"Exploring the Parameter Space of Nanoparticle Synthesis with Cesium Lead Halides"

This is a lab activity that is currently scheduled for the third lab session (week 4) in the course. The first two lab sessions will have explored some basic nanoparticle synthesis of metal and semiconductor nanoparticles; directly prior to this, the students will have just done a lab on the synthesis of CdSe nanoparticles where they synthesize different shapes of CdSe nanoparticles by controlling the time of the reaction. Here, they will instead be presented with a system where nanoparticle shape must be controlled via reaction temperature due to fast reaction kinetics. They will also be introduced to the concept of controlling nanoparticle shape using ligand. The lab is also meant to be exciting and timely, as these are hot materials in the field of nanotechnology right now.

Lesson Objectives

The lesson objectives for this laboratory activity are to:

- Synthesize a set of nanocrystals where the size of the nanocrystal is controlled by reaction temperature (rather than time)
- Synthesize two different compositions of lead halide perovskites, as well as their corresponding mixed halide
- Synthesize two different shapes of nanocrystals by controlling the types of ligands present in the synthesis

The course objectives that are related to this laboratory activity are:

- Identify the influence of nanoparticle size, shape, and composition on nanoparticle properties (such as lattice structure and optical bandgap)
- Explain how different synthetic techniques give rise to control over nanoparticle size and shape
- Employ these synthetic techniques in the laboratory to intentionally produce desired types of nanoparticles *(primarily achieved in lab)*
- Characterize nanoparticle properties in the laboratory using electron microscopy, x-ray scattering and diffraction, and optical spectroscopy *(primarily achieved in lab)*
- Clearly articulate the results of their research (in both written and oral formats) *(via the lab report)*

Timeline

Lab meets for a 3 hr time window from 1:20 – 4:20pm.

Time Block	Activity
1:20 – 1:35	Review of pre-lab work, procedure, safety, etc
1:35 – 2:20	Synthesis of $CsPbX_3$ nanocubes
2:20 – 3:30	Synthesis of $CsPbBr_3$ nanosheets
3:30 – 4:00	Characterization of $CsPbX_3$ nanocrystals
4:00 – 4:20	Clean-up

Lesson Assessment

There will be a formative assessment that accompanies this lesson in the form of a lab report. The introduction section of the lab report will give students an opportunity to summarize their knowledge of how synthetic procedures lead to variations in nanoparticle size and shape, and why these various nanoparticle sizes and shapes are useful. The results and discussion section will then allow students to demonstrate how these principles were shown in their own experiment and to clearly articulate the results of their own work with figures, tables, and discussion. The discussion will primarily be guided by discussion questions that are included in the lab handout.

Additional Materials

Attached, please see the lab handout that the students are provided as guidance for the laboratory assignment. The students will be asked to read through the handout, watch a lab technique video, and annotate the procedure before coming in to lab.

Reflection

This lesson plan is clearly connected to my larger pedagogical goals and course objectives as it is a lab experiment where I am encouraging students to make their own choices as they become more independent researchers. Although instructions are provided, particularly in the nanosheet synthesis I encourage them to make independent choices. However, the crux of the assignment is really in the discussion section where they are urged to consider how the choices they made in lab influenced the outcomes. As they progress through the course and then work on their final projects, these are the sorts of cause and effect relationships they will be answering as scientists.

Exploring the Parameter Space of Nanoparticle Synthesis with Cesium Lead Halides

Introduction

In this lab, you will have the opportunity to explore three aspects of cesium lead halide chemistry:

1. Size-dependent properties. As a class, you will synthesize four different sizes of $CsPbBr_3$ nanocubes by varying the reaction **temperature**.
2. Composition-dependent properties. The rest of the class will synthesize $CsPbI_3$, $CsPbBr_3$, and $CsPb(Br/I)_3$ nanocubes at a constant temperature to highlight how readily the optical properties of lead halide perovskites change simply via **halide ion substitution**.
3. Shape-dependent properties. In addition, everyone will synthesize $CsPbBr_3$ nanosheets by controlling the **ligand type** that is present.

Each group will synthesize one set of $CsPbX_3$ nanocubes and one set of $CsPbBr_3$ nanosheets. Data will then be shared among the class in order to allow for determination of trends.

Table 1. Group assignments for $CsPbX_3$ nanocube synthesis.

	Composition	*Temperature*
Group 1	$CsPbBr_3$	150 °C
Group 2	$CsPb(Br/I)_3$	150 °C
Group 3	$CsPbI_3$	150 °C
Group 4	$CsPbBr_3$	140 °C
Group 5	$CsPbBr_3$	170 °C
Group 6	$CsPbBr_3$	190 °C

Table 2. Group assignments for $CsPbBr_3$ nanosheet synthesis.

	Temperature
Groups 1, 2, 3	> 150 °C
Groups 4, 5, 6	< 150 °C

Synthesis of $CsPbX_3$ Nanocubes

Prior to lab, cesium oleate will be prepared for you by heating cesium carbonate (0.032 g) in 10 mL of oleic acid to 120 °C for 1 hr while degassing.

1. Prepare the following reagents:
   - 0.54 mmol PbX_2 – see Table 1 for group assignments
   - 1.5 mL oleic acid
   - 3 mL oleylamine
   - 15 mL octadecene

2. Degas the solution under N_2 at 100 °C for 10 minutes.
3. Once the PbX_2 solid has completely dissolved, heat the reaction mixture to your assigned temperature (see Table 1) and swiftly inject 0.55 mL Cs-oleate.
4. After 5 seconds, cool down the reaction vessel using an ice-water bath.
5. Centrifuge the reaction mixture.
6. Redissolve the precipitate in hexane.

Synthesis of $CsPbBr_3$ Nanosheets

1. Prior to arriving in lab, look up the procedure for synthesizing nanosheets in the Shamsi *et al.* reference. Decide with your lab group what size nanosheets you would like to target and note the necessary reagent amounts.
    - 0.013 g $PbBr_2$
    - ? oleic acid
    - ? oleylamine
    - ? octanoic acid
    - ? octylamine
    - 10 mL octadecene
2. Dry the contents under vacuum for 20 minutes at 100 °C.
3. Once the $PbBr_2$ solid has completely dissolved, close off the vacuum and introduce a N_2 atmosphere. Then, pick a temperature either below or above 150 °C (see Table 2; it is up to your group to decide how close or far away from 150 °C you would like to stray) and swiftly inject 1 mL of Cs-oleate.
4. After 5 minutes, cool the reaction mixture to room temperature using a water bath.
5. Once the reaction mixture has cooled, add 10 mL of hexane to the reaction solution and transfer it to a centrifuge tube. Centrifuge the solution.
6. Redissolve the precipitate in hexane.

Characterization

For each sample, measure the UV-vis absorption spectrum and emission spectrum.

Prepare a TEM sample for each of your nanoparticles by dropcasting a film of each of your solutions onto a TEM grid. Make sure to label them appropriately for your TA.

Discussion Questions

1. How does the emission of $CsPbI_3$ nanocubes relate to that of $CsPbBr_3$?
2. Why did we opt to use temperature as a way of controlling the $CsPbBr_3$ nanocube size in this synthesis? Could we use a constant temperature and vary time instead like we did last week with the CdSe quantum dot synthesis? Why or why not?

3. If you wanted to make a TV screen that operated off of $CsPbX_3$ perovskites, what reaction conditions would you want to choose for your blue, green, and red emitters?
4. Look up from the Shamsi paper what the role of the extra (shorter) ligands is in the nanosheet synthesis. How does it lead to nanosheets instead of nanocubes?
5. Measure the size of the nanosheets you made from your TEM images. How do they compare to the nanosheet size you expected to make? If there are differences, what could account for them?
6. How did increasing or decreasing the temperature affect the nanosheet synthesis? Was this similar to the way that temperature affected the nanocube synthesis?

References

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Sample Assessment

Below, I highlight the final project for my course, in which students are asked to design, synthesize, and characterize a nanoparticle system with a given nanoparticle application in mind. The decision to highlight this assessment in my course design project was straightforward, as this project was the focal point for my entire course. I wanted to design a laboratory-based course where students would be exposed to the different applications of nanotechnology and actually get to make and design these technologies – both the devices and their nanoparticulate components. This made implementing backwards course design highly necessary, as all parts of the course had to work together in order to prepare students to be able to complete this project within a one-semester time frame. Naturally, they will pick up the laboratory skills they need in the laboratory component of the course, but they will also work on locating and synthesizing information from the literature in the lecture component of the course, in preparation for when they will have to come up with an idea for their final course project.

Such a large project creates an opportunity to implement inclusive, learning-centered practices. I tried to vary the assessment types even within the project itself as a whole – for example, the research results are presented both in both a written and oral format, so that different students feel comfortable at different points. I think there is also simultaneously both a lot of structure and a lot of freedom in the project design—I have given students multiple steps and asked them to outline their projects, but overall there is still immense freedom in that they have full control over their project scope. However, I also plan to provide examples of projects they can take on for students who feel less comfortable designing an entirely brand new project on their own, so that those students still get the opportunity to show me that they are able to implement the skills that the course has taught them – such as obtaining information from the chemical literature, and synthesizing nanoparticles – without having to figure out what type of nanotechnology they would want to work with. Finally, the project introduces opportunities to incorporate integrated cultural frameworks into the more traditionally individuated scientific classroom. By working in the laboratory to gain familiarity with the course content, students will have the opportunity to learn by doing, rather than reading; additionally, the use of peer review during the intermediate writing stage of the project reports will encourage students to value other students' opinions, which is a vital part of effective communication.

Final Project

For the second half of the course, you will be working to design a nanoparticle system that can be implemented in a nanoparticle application of your choice. After deciding upon the desired application, you will use the literature to select an appropriate nanoparticle system and decide if you'd like to make any modifications. You will then have time in the laboratory to synthesize and then characterize your material, in order to assess its quality if implemented in your chosen application. At the end of the semester, you will present your results in both a written and oral format to your peers.

Some applications you may want to consider are:

- Solar cells
- Light-emitting diodes
- Transistors
- Photodiodes
- Biosensors
- …

In essence, the goal is to synthesize nanoparticles, characterize their properties, and then consider their use in a nanotechnology – such as a solar cell. The purpose is to apply the content we have explored and the skills we have developed so far this semester in an all-encompassing project.

To provide check points and feedback along the way, this project will be broken up into multiple assignments that will help you construct your system and analyze your results. In total, this project will be worth 30% of your course grade, broken up into the following components:

Synthesis and characterization plan	20 pts
Progress report	30 pts
Peer review of classmates' progress reports	20 pts
Final report	100 pts
In-class presentation	50 pts
Participation during in-class presentations	10 pts
Total	**230 pts**

Synthesis and characterization plan – Due December XX

For the first stage of your project, identify what nanotechnology you would like to target. Keeping in mind what types of properties a nanoparticle component must have in order to be a good fit for that type of nanotechnology, read through at least 3 papers in a search for a nanoparticle type that you could use for your project. Note any interesting details you find in these papers.

Based on the literature syntheses you find, develop a synthesis plan to follow in laboratory in the upcoming weeks. You are not required to make any modifications to syntheses reported in the literature, but you may wish to mix and match elements from different papers or try out certain modifications to improve the design of your nanomaterial for your specific nanotechnology.

In addition, develop a plan for what types of sample characterization you would like to do in the laboratory to evaluate your nanoparticle's properties. Over the course of the next several weeks in lab, you will have the opportunity to implement this plan!

Element	**Score**	**Max Score**
Application/nanotechnology is clearly identified		2
Key properties that a nanoparticle must have to be useful in that application/nanotechnology are clearly identified		4
At least 3 papers are referenced		3
A clear procedure for the nanoparticle synthesis is provided		6
The types of sample characterizations that will be used are outlined		5
Total		**20**

Progress report – Due December XX

In a lab report format, let us know how your project is going so far. Describe your synthesis and characterization methods. Analyze any data you've acquired so far from sample synthesis and characterization and place it in your results & discussion section.

This will also be an opportunity to draft an introduction section where you describe the reasoning for choosing your nanoparticle system for your targeted application and explain the relevance of your chosen nanotechnology to our society.

We will peer review these progress reports in class to provide feedback on each other's projects. The peer review process will be graded for completion; however, it should be viewed as a valuable opportunity to work on your feedback and evaluation skills.

Element	**Score**	**Max Score**
Introduction section clearly outlines the relevance of the nanotechnology application to society		2
Introduction clearly specifies the important nanoparticle properties required for efficient/effective nanotechnology		3
Introduction justifies the nanoparticle selected for this project		5
Methods section clearly outlines the synthesis that was followed		5
Methods section clearly describes any characterization techniques that were performed		3
Figures are well-presented: axes are labeled, numbers contain units, captions are present, ...		4
Tables are well-organized: numbers contain units, captions are present, ...		2
Results/discussion section identifies what has been completed so far and what the plan is for the remaining lab sessions		6
Total		**30**

Element	**Score**	**Max Score**
Peer review of classmate 1's progress report		10
Peer review of classmate 2's progress report		10
Total		**20**

Final report – Due December XX

Building off of your progress report from a couple of weeks ago, let us know how your project ended up working out.

Use the feedback provided by your peers to update your introduction section and make sure it clearly addresses the criteria outlined in the grading rubric. Similarly, update your methods and results/discussions sections, adding in your results from the last few weeks.

In the discussion, make sure to address whether the nanoparticle system you chose actually ended up being a good candidate for your type of nanotechnology. What criteria does one use to evaluate whether a device in your field is "good" or "bad"?

Introduction	20 pts
Methods	15 pts
Results	30 pts
Discussion	30 pts
Conclusion	5 pts
Total	**100 pts**

Guidelines for each section are provided below to aid you in developing your report.

Introduction:

- Clearly outlines the relevance of the nanotechnology application to society
- Explains the basics of the nanotechnology/device operation
- Clearly specifies the important nanoparticle properties required for efficient and effective nanotechnology/device operation
- Justifies the nanoparticle selection for this project and the decision to make any modifications from the literature

Methods:

- References the literature from which synthetic protocols were adapted
- Clearly describes the synthesis that was followed
- Describes any characterization techniques that were performed

Results:

- Figures are well-presented: axes are labeled, numbers contain units, captions are present, ...
- Tables are well-organized: numbers contain units, captions are present, ...

Discussion:

- Explains whether the product synthesized matched or differed from what was expected
- Explains what the characterization methods that were performed reveal about the nanoparticle's properties
- Explains what the characterization methods reveal about the nanoparticle's expected operation in the nanotechnology

Conclusion:

- Recaps the intended goals of the project and whether or not they were attained
- Offers a perspective on whether this nanoparticle system is useful in such a context

In-Class Presentations – Week of December XX-XX

During the final week of classes, you will present your results to your classmates.

Presentations will be evaluated based on the rubric provided below for a total of **50 pts**.

	Excellent	**Good**	**Fair**	**Poor**
Category 1				
Category 2				
Category 3				
Category 4				
Category 5				
Category 6				
Category 7				
Category 8				

Sample Evaluation

Below, I provide an example of the mid-term evaluation that will be given to the students in week 5 of the course. By this point, students will have turned in two or three lab reports, had two journal clubs, and submitted their first literature review. The evaluation will serve two purposes:

1) To determine what changes to the course should be made in future iterations of the course. Some questions, such as whether the course assumed too much background knowledge, and whether students liked certain lab activities, are about past experiences and cannot be changed for the students that are currently enrolled in the course. However, their experiences can be used to inform my decisions on how to teach the class in future years.
2) To determine what changes to the course should be made throughout the rest of the semester. Here, I am interested in how the activities that we do, such as pre-class work, journal club, lab activities, and the timeliness of feedback, are going so far. Based on the feedback I am given, I will work to modify those activities to create a better experience for my students. This course is intentionally structured around repetitive activities—journal clubs happen about every two weeks, there is a lab activity every week, etc—so it is important to make sure that these activities are helping students meet the course objectives I have laid out, and if not, to implement some sort of change to see if it'll result in an improved learning outcome.

The strengths of this evaluation are:

- It is quick to administer – it can be given in class and anonymously, basically ensuring a 100% completion rate
- It evaluates each component of the course to get a sense of how things are going overall
- It is specific – I am asking specific questions targeted at the areas of my teaching that I am most concerned about

The limitations of this evaluation are:

- The Likert scale questions really narrow the scope of the feedback I will get—it means I have to anticipate the areas I'll want to get feedback in, instead of allowing students to bring up the concerns they have naturally. However, the form asks for additional comments or concerns at the bottom of each section, with the hope that students will bring up any notable feedback when prompted.
- The feedback is limited to the questions I ask on the form. An open discussion format, like one where a mediator is present, would likely give me a different picture than what I will get from using this form.

Mid-term Evaluation

Thank you so much for your active participation these last few weeks in our class. I hope that this course has been engaging and interesting and that you have begun to develop new skills (and refine old ones!).

Please answer the questions below and provide detailed feedback where you are willing and able to do so.

Lecture

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I find value in the pre-class assignments we are asked to complete, such as watching videos, reading articles, etc.	1	2	3	4	5
This class moves at an appropriate pace for me.	1	2	3	4	5
I feel like I know where to start looking for papers in the literature.	1	2	3	4	5

Did this course assume too much background knowledge? If yes, what topics did you wish were covered more thoroughly at the start of the course?

Have journal clubs gone at a good pace? Do you need more help reading articles, or conversely, do you feel like we can go more in depth than we have been going?

Do you have any other comments or thoughts about the lecture part of the course?

Laboratory

	Not At All Useful	Not Very Useful	Okay	Useful	Very Useful
On a scale of 1 to 5, how helpful have the lab activities been in increasing your understanding of nanoparticle chemistry?	1	2	3	4	5

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
The pre-class activities are enough so that I have a good sense of what I am going to be doing in lab before I arrive.	1	2	3	4	5
When I get a lab report back, I know what I need to do to improve upon my writing and figure presentation skills moving forward.	1	2	3	4	5
Lab report feedback has been provided in a timely manner.	1	2	3	4	5

Please feel free to provide any additional comments on the lab activities here—what you liked, what you didn't like, etc.

Annotated Bibliography

The Teaching Certificate Program has provided me with the language and structure I needed to formulate a lot of the thoughts I'd had about teaching for many years. A lot of good teaching practices are intuitive, but when it comes time to actually implement them, it is actually difficult to put them into practice. Below, I've listed some of the readings that articulated effective teaching practices in a way that resonated with me. In many cases, I felt like I was already on the right track with my Course Design Project, but these readings motivated me to go back and modify my design in more intentional ways.

Ambrose, S. A.; Bridges, M. W.; DiPietro, M.; Lovett, M. C.; Norman, M. K. What Kinds of Practice and Feedback Enhance Learning? In *How Learning Works: Seven Research-Based Principles for Smart Teaching*, 1st ed.; Jossey-Bass, 2010.

> The main claim of this text is incredibly simple: Goal-directed practice coupled with targeted feedback is critical to learning. Thus, in my Course Design Project, I was reminded to make sure that if I wanted students to master a certain type of skill by the end of the course, I needed to give them ample opportunities to practice it throughout the course (goal-directed practice) along with targeted feedback. For that reason, I have repetitive activities: journal clubs are repeated multiple times, along with self-evaluations after each iteration; lab reports are submitted each week, with targeted feedback provided after each one, and these lab reports will prepare students for their final project which will be in a similar format.

Augustine, B. H.; Caran, K. L.; Reisner, B. A. An Evolutionary Approach to Nanoscience in the Undergraduate Chemistry Curriculum at James Madison University. In *Nanotechnology in Undergraduate Education*; ACS Symposium Series, 2010.

Brookfield, S. D. What Is Critically Reflective Teaching? In *Becoming a Critically Reflective Teacher*, 2nd ed.; Jossey-Bass, 2017.

Fink, L. D. Designing Significant Learning Experiences: Getting Started. In *Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses*, 1st ed.; Jossey-Bass, 2003.

> Fink's "Designing Significant Learning Experiences" provides a clear set of steps to integrated course design, in which the course learning goals, teaching and learning activities, and feedback and assessments all reflect and support one another. The process of designing an integrated course first entails building strong primary components; two of the biggest steps here are identifying situational factors and developing learning goals. In my Course Design Project, these two steps really constituted the bulk of the work. Understanding the situational factors (especially for a hypothetical teaching context) are critical to designing a learning-centered course; as Fink notes, the difference between teaching to twenty vs one hundred students is critical. Similarly, the development of learning goals, or course objectives, is essentially the linchpin upon which the entire course design relies; without course objectives, you are essentially designing the course blindly.

Klein, G. C.; Carney, J. M. "Comprehensive Approach to the Development of Communication and Critical Thinking: Bookend Courses for Third- and Fourth-Year Chemistry Majors." *J. Chem. Educ.* **2014**, *91* (10), 1649-1654.

> This article describes two courses used to "bookend" the third and fourth years of the undergraduate chemistry degree in which students develop communication and critical thinking skills. First, in the fall of their junior year, students take a course in which they research and write a literature review article, which they also deliver as a presentation to their peers at the end of the course. In the spring of their senior year, students write a grant in the process of designing their own research process. They then execute these projects, and at the end of the semester, they present their results at a department-wide conference. Evaluations of written and oral skills in years three vs four indicate improvement, though no controls were provided to establish a comparison for the improvement in skills that would be expected from students continuing their college education even without such a course. Ultimately, this article mirrors the same thinking I used in my Course Design Project, in that upper-level undergraduates should be working on developing research and communication skills.