2025, Volume 10, Issue 2

How AI Helped My Students Understand Procedures and Summarize Information in Inorganic Chemistry Laboratory

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Teaching students to do synthesis is analogous to learning to bake. When I was new to baking, I saw each recipe as a singular list of ingredients and directions. I didn't see a general method or approach to making, let's say cookies. As you start to read a recipe's introduction or the musings of a food blogger, you will more likely focus on this singular cookie recipe as opposed to pondering why cookies use baking soda and not baking powder. With limited experience, you would likely not know that you were following the traditional cream method that emerged in the 18th century and is used in many cookie recipes, or that baking soda makes cookies chewier. Over time through experience, you gradually learn the general method to make cookies or cakes or pies. You can also take a more direct approach to understanding why the creaming method is often used to make cookies, by asking AI not simply for a cookie recipe but for *how* you make sugar cookies. AI will explain the general approach for making cookies and why that approach is used.

Students new to working in a laboratory making molecules, called synthesis in the industry, only see a list of reagents and a procedure. Each procedure is a singular list of reagents and directions. Students follow this procedure to do this process. With limited experience, they do not see that they are following methods developed, tested, and revised over the last two centuries. Given time and with guidance, students start to understand that there are accepted methods to do synthetic steps, just like there are accepted ways to make cookies.

In past semesters in my synthetic inorganic chemistry laboratory, I would build an assignment where students are charged with finding an article in the primary literature with a similar synthetic process to what we would be doing in the lab. Finding and reading the experimental section from an article in the literature would show students how a similar reaction was conducted. It would, however, be a specific reaction, not a general approach. I had hoped for students to gain an understanding of the standard method of the process we were about to attempt in the laboratory. After reading the assignment, the students were to write a procedure for the reaction they were about to perform in the laboratory. The assignment, not surprisingly, didn't deliver the desired outcome. Students would skim

the experimental section and just substitute their reagents for the ones in the paper but not see a general method. In some cases, students would just rewrite the experimental section from the paper, without including anything about the reaction they would be performing in the lab. I had hoped that students would achieve a meta-awareness of what they would be physically doing in the laboratory, but they did not. As an assignment, it failed.

This year, I tried a different approach. There is a common chemical reagent called a Grignard reagent. Grignard reagents have been known for over one hundred years and their inventor, a French chemist named Victor Grignard, was one of the first Nobel Prize recipients. Any process that has been around for over one hundred years is bound to have a standard method with the process tested and improved over time for efficiency, safety, and yield. As we were about to do a chemical reaction in the laboratory using a Grignard reagent, I asked students to use AI how to determine how to use a Grignard reagent, summarize their findings and submit them before we did the Grignard reaction in the laboratory.

Just as if you asked AI to describe how to make cookies with a process and a reason, AI could describe how to make a Grignard reagent with a process and a reason. AI accomplished what my assignment did not. It gave a summary and an explanation of the thousands of experimental procedures involving Grignard reagents in primary literature. AI provided an accurate step by step general process of how a Grignard reagent is used in the laboratory much better than reading a single paper using a Grignard reagent. Students came into the lab with a greater understanding than in past years for why we were doing the physical steps in the lab. If students do not fully understand what they are doing in the laboratory, they will just go through the motions, and there is little chance that they will be able to solve problems and think critically about what they are doing. The improved understanding of the experimental process allows for enhanced problem solving and critical thinking in the laboratory.

An added piece to consider in the laboratory versus a kitchen is safety. Other than the occasional allergy, cookies do not pose a safety hazard. Not following a procedure in the kitchen can lead to a flat cake or inedible bread. Most reagents used in a laboratory, and nearly all in an advanced synthesis laboratory, pose some sort of safety hazard. Not following a procedure in the laboratory can lead to a safety incident such as a fire or release of a noxious gas.

A Safety Data Sheet (SDS) is a standardized document with sixteen sections written by a product's manufacturer meant to provide a comprehensive list of a product's or a chemical's properties, hazards, disposal methods and other information. SDSs, while full of information, are often long and can be difficult for students to find pertinent facts. There are guidelines to help readers make sense of SDSs. Many universities, companies and OSHA provide guidance on how to read an SDS. It is vital as part of a student's development that they learn to use SDSs to ensure their own safety and the safety

of those around them as they become independent workers in the laboratory.

For many years, in the inorganic chemistry synthesis laboratory, we have discussed SDSs. The first SDS we would discuss would be for silicon dioxide, more commonly known as sand. A seemingly safe substance, the SDS of sand includes a hazard warning since sand ground to a fine dust poses a breathing hazard. The second SDS would be for a more obviously hazardous material, often dichloromethane used commercially in paint strippers and a suspected carcinogen. The exercise was to show students how they can take control of their own safety by familiarizing themselves with the hazards of the chemicals they would be working with. Throughout the semester, I encourage students to read the SDSs of all chemical reagents and solvents that they will be working with in the laboratory. Very few students took the time to read over the SDS of a chemical species before using it in the laboratory. And seemingly, those who did read the SDSs still failed to gain perspective on what precautions would be needed when dealing with a specific reagent or solvent.

Since every manufacturer of a chemical posts their own SDS online, there are multiple SDSs for any species available. AI is very good at reading and summarizing information. For this year, in addition to asking students to read an SDS of a particular chemical species, I also asked students to use AI to write a chemical hazard statement based on the SDS and turn it in as an assignment. The submissions I received were clear and highlighted the most important aspects of the SDS. The assignment allowed students to quickly summarize an SDS and understand key points to working safely with a chemical species. This is where AI changed my view of its application to my teaching. After completing the assignment, students would, on their own, quickly ask AI to summarize the hazards of a chemical species that they would be working with in the laboratory. Using AI gave students not less ownership and concern for their safety, but more because it allowed them to find the information quickly and in a usable form. Students became more prepared to work safely in the laboratory because AI made safety information more accessible.

Any time students go into the laboratory, we want them to be prepared. Prepared students will better understand what they are doing in the laboratory and why they are doing it. They will also know the safety hazards associated with procedures. They will be able to problem solve when things do not go entirely as planned. Using AI improved my ability to build assignments to prepare students to come to the laboratory. The assignments take advantage of AI's ability to summarize and present information. Moving forward, I will continue to use AI as a tool to prepare students to work in the laboratory. It is more successful than other assignments I had tried.