View from My Classroom

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Student Opinions Regarding Inquiry-Based Labs

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As part of a research project investigating what high school chemistry teachers are including in their courses, teachers were asked whether they conduct inquiry-based labs. The survey defined inquiry as students writing their own procedures—regardless of where the purpose, problem, or question originated. Of the 571 responses to the online survey from high school chemistry teachers all over the U.S., 45.5% indicated that they did not use inquiry labs in their classrooms *(1).* While more than half of the respondents are incorporating inquiry, 45.5% is still a large number not using this useful teaching tool—especially considering the imperatives of the National Science Education Standards (NSES), which include inquiry standards *(2).* It is certainly not necessary, feasible, or appropriate to have all of a student's labs in this format; offering a few each year can still have enormous benefits.

Inquiry labs are prevalent in science education literature and teaching methods courses. Authors have defined inquiry *(3),* given suggestions and remedies for difficulties associated with inquiry *(4–6),* provided examples of inquiry activities *(7–21),* described how to convert conventional labs into inquiry labs *(22–23),* compared inquiry and conventional lab methods *(24–26),* given direction on assessing inquiry *(27),* shown evidence of inquiry methods affecting test scores *(28–29),* and even commented on the need to train graduate teaching assistants on inquiry methods *(30).* Recently, two issues of *The Science Teacher* have been devoted entirely to inquiry lab techniques *(31–32).* So why are so many teachers still not using inquiry? Perhaps they do not believe that the benefits are as substantial as the claims. Have high school student opinions on inquiry been documented and considered? No articles describing student comments on inquiry labs could be located within the current literature.

The study described here features comments from students in a high school chemistry course who were required to turn in portfolios of their work at the end of each semester. The students collected their best work satisfying a list of criteria. Brief reflections were written on why the piece was chosen and what they learned from the experience. In the portfolio, students included a laboratory for which they designed the procedure (an inquiry lab). The reflection pieces presented an opportunity to study student opinions on inquiry labs. The students in this course attend an urban, private, four-year high school with an attendance of approximately 500 students. The course consisted primarily of sophomores.

The comments from student portfolios are unedited quotes. Although these are only a sampling of student comments, they are representative of all the students' reflections.

Disadvantages for Teachers of Using Inquiry Methods

There are drawbacks to using inquiry techniques, which probably account for the large number of teachers that do not use this instructional method. Several are discussed below.

Loss of Control

Inquiry-based learning means that teachers do not always have control over exactly what students do. Although instructors are often wary of yielding control, students will eventually be in life situations without step-by-step instructions. Inquiry labs provide safe environments in which to practice these skills.

Safety Issues

Without instructor-written protocols to follow, the possibility exists that students might design an unsafe procedure. This is especially a concern for chemistry instructors. A safe environment can be created by an instructor explaining any potential hazards with the materials and reviewing student-written procedures before students are allowed to begin. These precautions will ensure that inquiry labs are as safe as conventional labs. Instructors should be certain the students understand that a teacher's signature does not indicate a procedure is "the correct one"—as students will usually assume—simply that the procedure is a safe one.

Use of More Class Time

Students need more time to write their procedures. With pressures to include more content in courses, it is difficult to justify spending 2–3 times more class time doing an inquiry lab than the same lab in a conventional format. The less help and hints given to students, the more time it takes to complete the process. This is one negative that an instructor will have to justify by weighing the benefits of inquiry.

Fear of Abetting Student Misconceptions

Students sometimes arrive at erroneous results, or fail to make appropriate conclusions based upon the results of their laboratory. No instructor wants students to think that science is somehow magic and only works for some people some of the time. Mixed results, however, occur with inquiry and non-inquiry labs and the best way to overcome this with either format is de-briefing sessions after the lab to find and correct these misconceptions.

More Time Spent Grading Labs

Inquiry labs do take longer to grade than worksheet-format write-ups. However, inquiry labs do provide a more authentic and thorough form of assessment than conventional labs, allowing a deeper grasp of a student's understanding. If rubrics are utilized to assess the students' work, grading is much faster and less subjective *(27).*

Listening to Student Complaints

Students tend to complain at first, but, as demonstrated by the student comments that follow, their comments change afterwards.

Most students first presented with inquiry labs do not know where to begin. However, the more they experience learning in this way, the better they perform, and with less distress. Some commonly heard student complaints are provided below.

Student Concerns of Learning Using Inquiry Methods

More Effort and Thinking Are Required

Inquiry labs do take more effort to complete than when students are given the procedure and the steps of analysis. However, students learn valuable lessons from the challenge and from their mistakes.

> It was a bit of a challenge…. I learned that there is a lot of thinking that goes into designing a lab and conducting an experiment. I also learned that if I don't think the whole process through, I could easily make a mistake.
>
> It was much harder than following a given procedure, but it was a good experience.
>
> It was one of the harder labs I have done thus far, and that is why it is one of my better pieces of work.

Fear of Being in Control

Just as instructors fear being out of control, students are afraid to be in control. For students accustomed to being told what to do in academic endeavors, it is a different and sometimes unsettling experience to solve an open-ended problem. Scientists often feel this uneasiness and it is good to let students know that they are not the only ones that fear the unknown.

> When designing the lab by myself, I found there to be a degree of difficulty, because I was only 'somewhat' sure of what steps to take next. I feel that this was a great learning experience because now I know what to do and what steps to take in the future.
>
> When I am given a procedure, I do as it tells me and know that I have done it correctly. When I design it for myself, I am not as sure that I did the lab correctly.

Positive Aspects of Using Inquiry Methods

Inquiry lab experiences contain many positive aspects for students that make the method worth using, aside from achieving outcomes promulgated in the NSES *(2)*.

Developing Mastery

Students experience pride and excitement from learning independently: they develop skills, they feel like scientists, and they have a sense of accomplishment.

> I learned from this lab that I don't need to rely on a book or a teacher to do everything for me. I can do some things by myself, and now one of those things is designing a lab.
>
> I think it's good for us to design our own labs once in a while. It gives me a sense of accomplishment. I sometimes like to do things on my own instead of having people tell me what to do all the time.

Learning the Scientific Process

Students learn that the outcome is not always predictable, and procedures do not always work as planned, sometimes giving surprising results. Often, scientists have to revise procedures numerous times before finding one that works.

> I learned a lot in the process of designing a lab, perhaps even more than I would learn from doing a lab where a procedure is already given. Since we were able to pick out our own constants and variables in the lab, we did not know what the outcome of the experiment would be.
>
> In the process of designing the lab myself as opposed to having the procedure given to me, I learned how crucial it was to pay close attention to writing out each step, and not to get ahead of myself. I learned that it is important not to overlook steps and safety procedures.
>
> By designing the lab, I learned just how exact the procedure has to be.

Increased Communication Skills

Students learn the need to explain their ideas with enough detail that another person could complete the lab with similar outcomes.

> I learned all of the steps that needed to be included so other people could duplicate the experiment. The [procedure] steps were the hardest to write because they had to be clear enough so that other people could understand what I was trying to say.
>
> It is easier for me to learn visually rather than just by reading directions and that had a major part in how I tried to word what I was saying. I wanted whoever would do my project (if they would have be exchanged or traded) to be able to visually picture in their heads what I was saying as they read the directions.
>
> I learned how to take what you see and put it into words and explain what is going on.

Learning Procedural Organization and Logic

Many students have written a procedure stating how to dissolve a substance and then, in a subsequent step, specify finding the mass of the original solid. When they perform their lab, they realize their sequence and logic errors and learn to think ahead next time. Also, students often begin their analysis and realize that they are missing information or they collected more data than they needed.

> I learned how to better organize the acquired data to make it easily accessible for equations and analysis.
>
> I saw that when you have a good procedure, your lab runs smoother and you get better results.
>
> Some things I learned how to do because I wrote the lab as opposed to the information being given to me are how to organize my work and procedure in the lab paper.
>
> By designing the lab myself, I learned how to plan and organize my ideas, and how to include every detail needed in order to complete this lab.

Better Performance on Non-Inquiry Labs

Many students commented that their proficiency at non-inquiry labs increased due to their experience with even the few inquiry labs they completed.

> It also enabled me to become more competent of the instructions that I was given at later times in labs that were

pre-written for me. I would reflect back on what I had written in this lab to determine what I was to do when directions or steps were confusing me. I also became aware that writing labs is a difficult process, but a very useful one, after realizing the effects that this lab had on my future work.

Writing a lab also helped me to better understand reading a lab that is given to me. By knowing what a lab writer must do and understand and the tools that they use, I have been able to find a better understanding of the lab to be performed.

Learning the Chemistry Concepts

Students feel as if they understand the concepts in greater depth as a result of conducting inquiry labs.

> If I had already had a procedure to follow, instead of designing my own, I probably wouldn't have thought about the lab as much, or had gotten as much out of it.
>
> When I'm just following a procedure that I am given I don't pay attention to why you need each step I just do what is asked of me. When designing my own I was able to realize the why and understand the lab better.
>
> I believe that having contemplated and then decided what was the proper procedure, myself, I have a better understanding of why certain steps are taken than if I was told exactly what I needed to do.
>
> When you're given the procedure, you do not have to think about it, you just have to do it.
>
> I think you understand a lab a lot better when you have to write everything yourself. You have to know exactly what you are talking about for the lab to make sense.

Improved Ability To Correct or To Explain Mistakes or Erroneous Results

When students use self-designed procedures, they can quickly pinpoint errors in the procedures when results are not as expected.

> I learned how much thought and time is put into creating a lab. I learned that designing your own lab makes the experiment easier, because if you mess up, you'll be able to figure out why faster.

Increased Interest

Most students think it is more fun to work on something of their own creation.

> I had fun designing an experiment and it was fun to see that the experiment worked.
>
> I think that having us design our own experiment is a good way to get teenagers interested in chemistry labs. Instead of reading stuff off from a sheet of paper, we must come up with it on our own. It is just more exciting.

Conclusion

This article is not intended to imply that all laboratories should be inquiry-based. Certainly there are times when it is more appropriate to give students a procedure; for example when a particular technique is being taught. There are also benefits to students learning how to read and perform a given set of steps. Students can still experience in-depth analysis and understanding with good questioning and discussion after a non-inquiry lab. However, the inconveniences that inquiry may cause an instructor or students are outweighed by the benefits to the students. Therefore, inquiry-based approaches should be used as often as is practical. If students perform even a few inquiry-based labs each year throughout their middle school and high school careers, by graduation they will be more self-confident, critical-thinking people who are unafraid of "doing science".

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