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General Chemistry Students' Goals for Chemistry Laboratory Coursework

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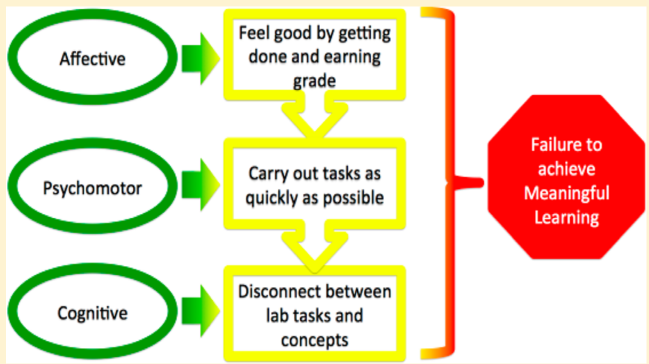
Supporting Information



ABSTRACT: Little research exists on college students' learning goals in chemistry, let alone specifically pertaining to laboratory coursework. Because students' learning goals are linked to achievement and dependent on context, research on students' goals in the laboratory context may lead to better understanding about the efficacy of lab curricula. This study characterized undergraduate students' learning goals for general chemistry laboratory coursework by recording video of students completing laboratory experiments and interviewing the students about their experiences. The data was analyzed utilizing the framework of learning domains as described by Human Constructivism. Students were found to be primarily guided by affective goals, such as the desire to feel good by completing the requirements and getting done early. This stood in conflict with any psychomotor or cognitive goals they held concurrently. The data provide suggestions for reform of the general chemistry laboratory curriculum.

KEYWORDS: *First-Year Undergraduate/General, Chemical Education Research, Laboratory Instruction, Testing/Assessment, Student-Centered Learning*

FEATURE: Chemical Education Research

Laboratory experiments, which have been described as a "necessary and important" part of science coursework,[1] are purported to support many aspects of learning chemistry. In describing these educational outcomes, researchers include learning social and technical skills, concepts and facts about science, scientific process skills, and deepening students' understanding about the nature of science.[2,3] In the past few decades, much research has been devoted to improving the efficacy of laboratory courses to achieve these outcomes; unfortunately, far too few of the results and recommendations have been realized in practice.[2,4]

One avenue to investigate the source of the discrepancy between the intended learning objectives and actual outcomes in laboratory experiences lies within constructivist theories of learning, which emphasize the role students play in their own learning. If students are responsible for constructing their knowledge, their goals for learning must be considered. Thus, investigations on student perspectives of laboratory coursework may provide valuable insights into improving the laboratory curriculum.[5]

BACKGROUND

There is a great deal of evidence that indicates the importance of students' goals and goal-setting behaviors for their academic performance.[6−8] However, goal setting is a complex process: students may pursue multiple goals simultaneously, they may hold conflicting goals, and their goals may change depending on the classroom context.[9]

Although work has been done to characterize the goals of chemistry faculty for laboratory coursework,[10−13] students' goals may vary greatly from their instructors' goals.[9] In fact, Hofstein and Lunetta[2] posited that a mismatch between student and instructor goals thwarts learning in laboratory coursework.

Human Constructivism[14] emphasizes a joint role between student and instructor in construction of new knowledge. The instructor may select appropriate material for the learner, but the learner must choose to commit herself to meaningful learning instead of relying on rote memorization. Meaningful learning, or the purposeful integration of new knowledge within a student's existing framework of knowledge, occurs at the confluence of the cognitive, psychomotor, and affective domains of learning.[15] These three domains have been used to analyze the goals of chemistry faculty,[10] but without understanding the students' perspectives, little can be done to examine the alignment between student and faculty goals.

RESEARCH QUESTIONS

Understanding students' goals both in the context of the laboratory and in light of the faculty members' goals is necessary in order to better understand "the appalling lack of

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effectiveness of laboratory instruction".[14] Thus, this study sought to answer the following questions:

- What do students enrolled in a general chemistry course hope to accomplish in the laboratory across the cognitive, affective, and psychomotor domains of learning?
- How do the goals of general chemistry students majoring in nonchemistry STEM fields compare to the goals of faculty members?

METHODS

To more accurately understand the complex and context-dependent nature of students' goals, a rich, descriptive data set was necessary. Video and interview data was collected using the video stimulated recall (VSR) technique.[16] VSR is an especially appropriate method for this investigation because it allows the participants to view and comment on what they are doing (psychomotor) as the interviewer inquires about how they were feeling (affective) and what they were thinking (cognitive). As its name indicates, VSR offers the additional benefit of improving participants' recollections of the prior day's activities. After obtaining consent according to IRB-approved protocol, a pair or group of four students was video recorded over the course of one lab period. The video was immediately reviewed by the researcher. Passages were selected to serve as interview prompts, with the interviewer showing the clips to each participant within 24 h of the laboratory period.

At the beginning and end of each interview, the participants were asked what they had hoped to accomplish during the lab. This, along with questions about each student's class standing and major (summarized in Table 1), was the only part of the interview that was scripted. The remainder of the participants' responses during the 40−60 min interviews were generated by showing the participant a video clip, followed by prompts such as "Tell me about this clip." or "What were you doing?", "What were you thinking?", and "How did you feel about that?". Approximately 10 clips, or about 7 min of video, were shown to each participant. Selected clips focused on events where the student was required to make decisions, such as uncertainty over the procedure, discussions with partners, questions asked to the teaching assistant, or mistakes made in carrying out the experiment.

Table 1. Participant Demographics

Year	Major	Participants
Freshman	Animal science/preveterinary	3
	Engineering	19
	Food science	1
	Geology	1
	Premed	3
Sophomore	Computer science	1
	Math/physics	1

In this manner, 31 students were filmed and interviewed, representing 9 different experiments and 13 different lab sections. Each participant was filmed and interviewed regarding a particular experiment. The students were enrolled in a first semester general chemistry course intended for students pursuing a degree in a science, technology, engineering, or math (STEM) field at a Midwestern research university. Most participants were first year students intending to major in engineering. This is reflective of the makeup of the course, which is taken primarily by freshman engineering students. Students declaring their major as chemistry were enrolled in a separate course and are not described in this study. The students were concurrently enrolled in a general chemistry lecture course, with graduate teaching assistants teaching the laboratory portion of the course. For all but one of the lab experiments, students were provided a procedure to follow. (See Supporting Information for description of experiments, including the purpose or goal of the lab as stated in the laboratory manual.) Students worked in pairs or in groups of four during the lab period, completing a joint lab report that was submitted prior to leaving the class.

To evaluate the degree of correspondence between student and faculty goals, student goals were coded using a list of a priori codes was generated using a comprehensive list of laboratory goals.[13] Additional codes were created when students expressed additional goals that were not included in the original list. Three transcripts were coded by two additional researchers. Fleiss's kappa was used to calculate inter-rater reliability.[17] Moderate agreement[18] was achieved when coded independently (k = 0.527), and after discussion among the three coders, near perfect agreement[18] was achieved (k = 0.905).

The coded goal statements were analyzed using a variable-oriented approach[19] via the lens of Human Constructivism,[14] which describes meaningful learning as the confluence of three learning domains: cognitive (thinking), psychomotor (doing), and affective (feeling). Many of the participants' statements reflected areas of overlap between or among the domains. For example, a statement such as "I want to do the lab quickly because it's boring and I want to get out sooner" reflects goals in the psychomotor and affective domains, i.e., do the lab quickly and avoid the negative feeling of boredom. The context of the participants' statements within the interview and the observations of the participants in lab were used to triangulate the categorization of their statements into the various learning domains.

Limitations

Because the number of participants (n = 31) was relatively small to the population of the course (N = 2173), this should not be interpreted as a representative sample. No data on students' performance in the course were collected, so it cannot be determined whether the sample was representative according to academic performance. During the recruitment phase of this study, many students rejected an invitation to participate, remarking that they were too self-conscious or too unsure of their ability to carry out the experiment, which indicates there may have been a selection bias toward students who were more confident in their laboratory abilities or higher-achieving students. Also, the distribution of participants according to academic program was heavily skewed to students pursuing degrees in the field of engineering; students majoring in chemistry or students in non-STEM disciplines may hold different goals. Finally, the participants at this institution may not be representative of a national sample. This particular institution's engineering program is highly competitive and ranked in the top 10 nationally, which again may lead to a selection bias of higher-achieving students.

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FINDINGS

When faculty are interviewed about their goals for general chemistry laboratory work, they cite fostering teamwork skills, teaching laboratory techniques and skills, and connecting laboratory with concepts and content learned in lecture.[10,12] In addition to these specific skills, it has been found that faculty focus primarily on cognitive and psychomotor learning, with few goals for the affective domain.[10] At the beginning and end of each interview, the student participant was asked an open-ended question about his or her goals for that laboratory experiment (Table 2). Many students (77%, $n = 24$) responded by quoting or paraphrasing the purpose or goal of the lab that was written in the lab manual (see Supporting Information). The same amount said that their goal was to complete the experiment, with some specifying that they wanted to complete it ahead of the scheduled time.

Table 2. Student Goals for Lab Coursework

Goal Statement	Students Who Described as a Goal (n = 31) Number	Percentage	Applicable Learning Domain(s)[a]
Statement of objective provided by manual	24	77	C, P
Finish experiment (early)	24	77	A, P
Avoid mistakes/get the right answer	17	55	C, A, P
Grade objective and course requirement	16	52	C, A, P
Techniques and skills	12	39	C, P
Content/reinforce lecture	8	26	C
Prepare for future	6	19	C, P
Group work/collaboration	5	16	C, A, P
Data manipulation	5	16	C
Nonchemistry specific affective goals	5	16	A
Active participation	5	16	P
Problem solving	2	6	C
Know why we are doing this	1	3	C

[a]Indicates cognitive (C), affective (A), and psychomotor (P).

Students were more likely to describe psychomotor goals when asked what they had hoped to accomplish at the beginning of the interview. Only three students described cognitive goals at the beginning of the interview when asked what they had hoped to accomplish. However, over the course of viewing the clips and discussing their experiences with the interviewer, an additional seven students described cognitive goals at the end of the interview when the question was repeated (Figure 1). Some of the goal statements in Table 2, such as finishing the experiment early, cannot readily be assigned to a cognitive, affective, or psychomotor domain. However, as the students viewed the clips and described their experiences, they provided insight into their reasons for pursuing a particular goal, which allowed further analysis of the students' goals within the framework of cognitive, affective, and psychomotor learning domains.

Affective Goals

The most prevalent goal described by students ($n = 24$) was to complete the lab experiment, often with an emphasis of getting done as soon as possible. This goal might at first seem difficult to categorize, with potential arguments for assigning it to any of the three learning domains. However, the interviews revealed further information about their motivation for the goal that indicated that it is primarily driven by related affective goals. Students frequently described feelings of enjoyment due to finishing early and feeling bad about being the last to complete the experiment.

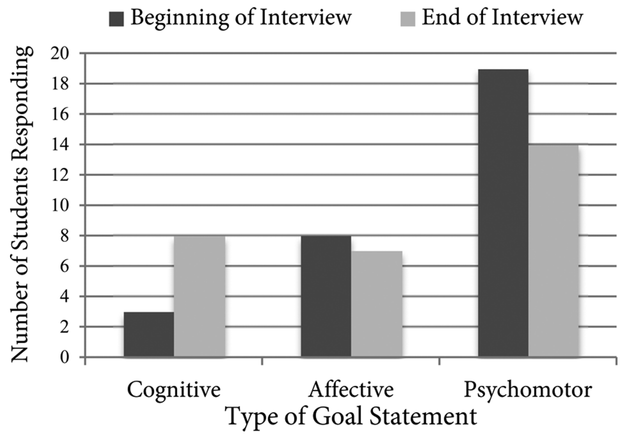

Figure 1. Prevalence of students' goal statements according to learning domains, when asked directly about their goals for the laboratory session.

> Tasha: ...We learned something that we normally wouldn't have learned if we hadn't screwed up.
> Interviewer: Ok. That's interesting. So screwing up is an opportunity to learn something new.
> Tasha: Yeah. Still makes me angry, though.
> Interviewer: Why, can you just say, for my benefit, why it makes you angry?
> Tasha: Because it puts us back a little bit, if we have to like put in an extra calculation or ask the TA. Because it's a three hour lab. Nobody wants to be there the whole three hours. I don't have anything better to do, I just don't want to be there. (laughs)

In addition to the positive feelings associated with completing the assignment early, students also described feeling good when they earn good grades. David explained, "...the second lab before this was the first time that we didn't finish last. So that was kind of fun. We're always last, but we get like, high grades, so it doesn't matter." Another student, Albert, remarked how he was pleased to have earned an A after viewing a video clip where he received his graded work from the previous week. Together, this desire to earn a good grade and finish the work in as little time as possible led students to identify the avoidance of mistakes as an important goal in their lab work. Many students associated making mistakes with negative emotions.

> Dustin: I don't know, I just have bad feelings about chemistry because back in high school, chemistry was super hard.
> Interviewer: What kind of bad feelings do you have?
> Dustin: I don't know, I just have bad feelings about it. Uh, back in high school I always made stupid mistakes and that always, one mistake leads into more mistakes and they're giant, so my answers in the end would always be vastly different from other people's answers.

Beyond making students feel bad, mistakes affected the students' self-images. They described themselves as doing things correctly and not making mistakes. Elliot said, "I'm the

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type of person that I want everything to go right and if it wasn't working I would've been upset." Eric ascribed his desire to do things correctly to his being a "perfectionist". Bethany agreed.

> Bethany: Yeah. I don't know. I'm one of those people who like to do everything to my best. ... I'm constantly trying to be the best and do the best and if it's not the best then it's not good enough. I just like to do things well.

Despite these attestations that they wanted to "do things well", a closer examination of the participants' goals in the psychomotor domain, and their actions in relation to their goals, revealed that this was not accomplished by most students.

Psychomotor Goals

Students described learning techniques and skills as a goal for their laboratory course (n = 12), but their behaviors as observed in the video and described in the interview seemed to contradict that goal statement. Students were observed eschewing opportunities to try or practice techniques precisely because they lacked proficiency. For example, Sherri declined an offer from her lab partner to use the buret.

> Sherri: About using the buret, I just wasn't comfortable doing it, because I didn't feel like I was good enough using it to be accurate enough and he had done all the other [measurements with the buret]. And we felt like he did a pretty good job, or looked like he knew what he was doing.

Mason explained why he allowed his lab partner to pipet throughout the experiment instead of taking a turn.

> Mason: I can use a pipet, I just, I'm not the quickest with it. Like I bet Darren is quicker than I am at using it, just because he knows how to manipulate the um, what's the thing at the top, like the... actual name of the part...
> Interviewer: The bulb?
> Mason: The bulb, yeah. He knows how to use that better than I do.

Unfortunately, Darren was also focused on the length of time that pipetting required, so he modified the technique in order to make it faster.

> Darren: For the more impatient one. Instead of waiting for the [solution] to slowly get out of it, you can just push it out with the top bulb.
> Interviewer: Push it out with the top bulb? So did you end up pushing the solution out with the bulb?
> Darren: Yeah. Eventually, yeah.
> Interviewer: Ok. And why was that?
> Darren: Because it was like, I noticed that there was some barely in the very tip of it that gravity wouldn't have let down, so I just pushed the rest of it out to make sure we had it all in the actual beaker itself.

Mason was willing to forgo the opportunity to improve his ability and confidence at pipetting so that his group would finish the experiment faster. And Darren, in his hurry to finish the lab, deviated from the provided instructions and introduced additional error in the measurement.

Despite Darren's modification to the instructions for pipetting, most students did not have any inclination to modify the procedure or think critically about the steps they were carrying out. For example, Bree, Fred, and Samantha followed the steps provided in the procedure without understanding their purpose.

> Interviewer: Ok. Why did you make a graph of that?
> Fred: The procedure told us to.

> Interviewer: Do you know why you were trying to get those specific amounts?
> Bree: Because it said to.

> Samantha: So I always double-check my procedure. Like my procedure is my life in lab.
> Interviewer: Why do you do that?
> Samantha: Because I just want to make sure I know what I'm doing, I don't want to have to remember everything that I'm doing. There's no way I can remember all of that. I feel like my brain is so overloaded.

Not only did Samantha emphasize following the instructions, she did not realize that understanding the procedure she was carrying out would alleviate the cognitive burden of memorizing all of the steps.

This following the procedure without thought led to the phenomenon of students who were able to recite the steps that they followed, but unable to describe the conclusions they had reached in the corresponding laboratory reports that had been submitted by the end of the class period. In one experiment, the groups were tasked with determining whether broccoli stems or florets offered a greater amount of dietary iron. This was accomplished by ashing the vegetable, dissolving the iron, forming the colored ferroin, and using a spectrophotometer to construct a calibration curve and calculate the unknown concentration of iron in the vegetable samples. Despite students' abilities to describe these steps to me in detail, they could not discuss the results of the experiment. Kacie commented that she was "Glad that we had finished, I guess," while Spencer, another member of her group, was unable to describe his results other than they were "consistent with the rest of the class." Bree, who performed the same experiment in a different group of students, also could not recall which part of the broccoli contained more iron.

> Interviewer: Did you compare your floret sample to the stem samples?
> Bree: Yes, I think. (pause) Yeah. Yeah.
> Interviewer: How did it come out?
> Bree: Honestly, I'm not sure.
> Interviewer: Like if I'm anemic, what am I supposed to eat, which part of the broccoli?
> Bree: I'm honestly not sure. That was a main part of the lab. But I forget. It was the end of lab and I was...

Thus, to many of the students, the act of carrying out the directions was purely a psychomotor task, and was separated from the cognitive domain.

Cognitive Goals

It seemed encouraging that most students were able to quote or rephrase the objective for the experiment that was provided in the lab manual (n = 24). Yet the ability to recite the objective did not translate into an ability to identify conceptual goals for the experiment. Darren summarized the tasks of the experiment, which was to analyze a colored iron phenanthroline complex via spectroscopy. But he did not seem to consider the chemical reaction that was occurring as he mixed the two colorless reagents. Furthermore, throughout the interview, he confused the identity of phenanthroline with phenolphthalein, which had been used in a previous experiment.

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This can partially be attributed to lab manual itself, which described the goals of the experiment as a list of tasks, much as Darren did, and did not reference the chemical concepts. Another student who was interviewed after performing the same experiment referred to spectroscopy as a way to "determine the concentration without doing a titration", but was unable to describe the circumstances in which it would be appropriate. Nathan was another student who was interviewed after performing the same experiment.

> Nathan: Either the higher concentration the deeper the color it is, like the red, and then the lower that would be toward the orange, or the other way.
> Interviewer: Ok. And do you know why in lab they gave you those different colors? Did it matter?
> Nathan: It's more bright, so you won't mix everything up.

He was able to articulate the lab manual's objective and describe the relationship between concentration and color, but did not realize that the color itself was what allowed the spectrophotometric analysis to be performed.

Earning a grade or credit for the course was frequently named as a goal by students ($n = 16$). This may be construed to mean that the students want to gain a deep understanding of the course content, especially since eight students listed learning chemistry concepts or content as a goal. However, the interviews revealed that this was not the case. For example, Albert expressed his desire to get a good grade and emphasized that he wanted to understand the material, but rather than gain that understanding while working through lab, he said he would be able to do it later.

> Interviewer: Did you think about maybe asking other students, your TA, the professor?
> Albert: I know that a lot of the other students are in the same boat that I am, they're first year chemistry students. The TA, I probably could've asked her, she was busy, and you know, at this point, truthfully, I just wanted to get the experiment done. I can worry about the conceptual learning later.

Kristin had also decided to learn the material at a later time.

> Interviewer: So you're ok with [not understanding]? It still works for you?
> Kristin: I mean, it works because the exam's coming up so I'm going to study, and I'm going to figure it out today or tomorrow, so it doesn't bother me.

Samantha was asked if she had considered the molecular interactions that were occurring during the titration she performed.

> Samantha: I feel like they must be coming together and that's why we're mixing. Maybe the molecules have to be equal? I don't know what happens to the molecules when they become stabilized. I don't know. But, I'd like to know.
> Interviewer: Ok. So do you ask those questions?
> Samantha: Not really. Because there are so many other questions. Like, questions on homework and questions on handouts that they give us and I feel like there's not enough time to get my questions answered. So I try to focus on what's going to be on the exams because obviously that's the stuff I'm going to have to know. Sadly.

Albert's and Kristin's decision to delay their pursuit of conceptual understanding may have been due to a desire to leave lab early, or, like Samantha, they might have felt that there was not enough time provided. Indeed, students seemed to be more deeply swayed by the exam content than that of the lab reports. The first experiment asked students to perform titrations, comparing the accuracy of using a pipet or graduated cylinder to measure the titrand. After the experiment, Bethany seemed to think that the pieces were equivalent, even though she acknowledged that her results provided evidence to the contrary.

> Bethany: I don't think [measuring with the pipet instead of the graduated cylinder] made that much difference. In my opinion. But our results, I think it showed the pipet was more accurate, I think. I'm trying to remember. Yeah, I think it did. But just a little bit more. I don't really think it makes that much difference. But I don't know.

This phenomenon did not seem unique to Bethany. On the subsequent exam, students in the large lecture course were asked to identify the piece of glassware with the most accuracy, and only 46% of students were able to select the correct choice. However, in interviews that were conducted following that exam, participants recognized the difference in accuracy.

> Interviewer: Now what were you telling him there?
> Nathan: Telling him the pipet is more accurate than the volumetric-- uh, the graduated cylinder.
> Interviewer: Ok. Why do you think that?
> Nathan: Because I got that question wrong in the exam.

> Interviewer: Can you rank it or compare it to other glassware? For how accurate it is?
> Sherri: Well I know from my test that it's the most accurate we've used. (laughs)

Even though Nathan and Sherri had both participated in the same lab that Bethany did requiring students to compare the relative accuracy of glassware, they cited the exam question as the source of their knowledge.

Discordant Domains

A comparison of the students' goals with respect to the goals of faculty members reveals substantial misalignment. When given an opportunity to describe their goals, students did cite some goals that have been reported among faculty,[2,10−13,21,22] such as learning techniques and skills, learning content associated with the lecture, and working collaboratively with classmates, but none of the students' top four most frequently described goals correspond to any previously reported instructors' goals for laboratory coursework. Other goals of chemistry faculty, such as a deeper understanding of the nature of science, learning experimental design, improvement of writing skills, engaging in the work of scientists, and the investigation of phenomena, were not mentioned at all by the students.

In addition to the poor overlap with the goals of chemistry faculty, student often held multiple goals that were often in conflict with each other, particularly across the learning domains. Human Constructivism posits that meaningful learning occurs at the overlap of cognitive, affective, and psychomotor domains. The goals within the affective domain (e.g., to feel good by getting done early) were in conflict with psychomotor and cognitive goals (e.g., to spend time practicing techniques and understanding concepts). To increase their feelings of enjoyment and confidence in lab, students employed strategies to complete the lab as quickly as possible. Their affective goals superseded and required forfeiture of other goals, leading students to make compromises in their psychomotor

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and cognitive learning. Interestingly, while students prioritized goals in the affective domain, chemistry faculty more frequently described goals in the psychomotor and cognitive domains.[10]

The students also held the respective goals within the psychomotor and cognitive domains separately. Instead of seeking to integrate the cognitive and psychomotor domains and understand why they are carrying out certain steps or techniques, or to build conceptual understanding based on the experiments that they perform, the two domains remained distinct, with students uncritically following directions and deciding to pursue conceptual understanding outside of the laboratory context. This separation between the cognitive and psychomotor domains and their conflict with the affective domain hampered meaningful learning (Figure 2).

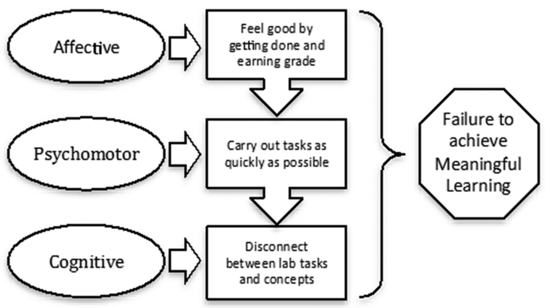

Figure 2. Relationships among students' primary goals for laboratory coursework.

IMPLICATIONS

One way to help students overcome the conflict between their goals in the affective domain and the goals in the psychomotor and cognitive domains would be to eliminate the possibility of leaving lab early. Without the incentive of leaving lab early, students may be more likely to engage in all of the lab tasks, including those tasks with which they are unfamiliar or lack confidence. The incentive to have the fastest and most proficient student to perform each task, as illustrated by Mason and Darren, would be eliminated, allowing each student to practice the techniques. Eliminating the incentive to carry out the tasks quickly may also increase students' level of cooperation, encouraging them to participate in discussions with their partners and pursue understanding in class as co-constructors of meaning,[2,23] rather than deciding to address their questions at a later time.

Students who complete the experiment before the class period ends could be provided with an opportunity to engage in guided reflection on the experiment until the end of the allotted time. Deliberate reflection may increase students' meaningful learning.[20] The increase in the number of students who described goals within the cognitive domain at the end of the interview confirms that additional reflection on their experiences can encourage students to focus on cognitive goals.

In addition to reallocating the way that time is spent in lab, experiments should be designed so that each student can participate fully in every part. Lengthy procedures that require students to divide the lab tasks and assign roles should be avoided. The interview data suggests that this division of labor diminishes the students' awareness of the tasks their partners perform; students observed carrying out experiments that explicitly required division of labor were much less likely to have a full understanding of the experimental procedure, analysis, or results. The lab period must provide enough time and instructors should facilitate full participation from all students.

By providing enough time for each student to be engaged in the entirety of the experiment, each student can be held individually accountable in the assessment portion of lab. Although individual lab reports may require a greater effort in grading, lab reports shared by partners or groups do not adequately assess individual students' learning. This was evidenced by the great number of students who were unable to answer questions during the interview that were included on the lab report, which had been completed and submitted the day prior. An alternative to requiring individual lab reports would be to include assessment of laboratory concepts and skills on homework assignments and exams. In light of the participants' emphasis on finding the "correct" answer and avoiding mistakes, assessments should be designed reduce the emphasis replication of a specific answer.[24] Students should be encouraged to view mistakes as opportunities to learn new skills or concepts, as well as explore the possibility of multiple correct answers.

Providing the students with a comprehensive list of learning goals may also help bring students' goals into alignment with the goals of chemistry faculty.[13] Students were very adept at reciting the procedural objectives that were provided in the laboratory manual for each lab experiment, emphasizing the importance of clearly articulated goals.[12] If the manual had enumerated conceptual goals as well, students may have been able to provide more elaborate descriptions of their learning goals in the cognitive domain, or might have chosen to pursue conceptual development during the lab period. Experiments also must be carefully selected and structured to support conceptual learning and connect the laboratory experiments to content that the students are learning in the lecture portion of the course.

CONCLUSIONS

It may not be a deep revelation to anyone who has participated in a general chemistry laboratory course that many students (77%) aim to complete the work as quickly as possible, and many (52%) describe fulfilling the necessary requirements to earn a grade or credit for the course as a goal. However, these data should call attention to the need and provide motivation for further reform of general chemistry lab courses,[1,2] especially courses designed for nonchemistry STEM majors, who may be less likely to have an inherent interest in learning chemistry, or first year students, who may not have sufficient maturity or experience to fully engage in opportunities for learning in a laboratory course. Until sufficient reforms are carried out, students will continue to prioritize the goals which are required for them to continue on their desired career paths: completion of the lab, earning a grade, and passing the course. Lab courses intended to fulfill deeper goals than these must be purposefully designed to do so.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.5b00463.

A list and brief description and the goal or purpose of the laboratory experiments that were observed (PDF, DOCX)

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Notes

The authors declare no competing financial interest.

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