# Scaffolding STEM Classrooms to Integrate Key Workplace Skills: Development of Resources for Active Learning Environments

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*Active learning classrooms provide an ideal opportunity to develop key workplace skills such as teamwork, information processing, critical thinking, and problem solving. Although many active learning pedagogies implicitly support student development of these skills, the role of the instructor in explicitly prompting and assessing these skills in the classroom is important. Integrating workplace skills in large-enrollment classrooms can be challenging, even with the support of teaching assistants (TAs). Using formative feedback from both students and TAs, the instructor developed resources and modified classroom facilitation to encourage development of workplace skills in an active learning Process Oriented Guided Inquiry Learning (POGIL) organic chemistry course. The resources developed include TA training activities, workplace skill rubrics, and course materials. Training activities help TAs understand course content and structure of course materials, facilitate POGIL classrooms, and become familiar with different workplace skills. Rubrics provide instructors a means of identifying and assessing student interactions for evidence of workplace skills. Guided-inquiry course materials highlight the importance of workplace skill objectives in addition to traditional content objectives.*

Most employers emphasize the importance of workplace or "soft" skills such as problem solving, management, creative thinking, leadership, communication, teamwork, and metacognition. However, development of these skills is often lacking in the typical college classroom, necessitating the need for employers to provide additional training. A report from 1990 provided training tips for employers aimed at helping their employees gain proficiency in these important workplace skills (Carnevale, Gainer, & Meltzer, 1990). More recent reports (Brewer & Smith, 2011; National Research Council, 2012; Singer, Nielsen, & Schweingruber, 2012) describe the need for scientists to be capable of reasoning, solving problems, communication, and collaboration with colleagues in other disciplines. Workplace skills are critical for success in the workplace and provide valuable tools for achievement in active learning classrooms. Although these skills are frequently recognized as being important attributes for professional success, in academic settings emphasis has traditionally focused more on content knowledge than development of the aforementioned skills.

One active learning pedagogy that supports explicit development of workplace skills, referred to as *process skills*, is Process Oriented Guided Inquiry Learning (POGIL; Hanson, 2006; Hanson & Wolfskill, 2000; Moog et al., 2006; Moog & Spencer, 2008). In a POGIL classroom, students work on structured activities in teams of three to four students. These activities are based on the constructivist theory of learning, where students construct their own knowledge by answering a series of guided questions (Vygotsky, 1978). These guided questions follow a three-stage learning cycle (exploration, concept invention, application) consisting of questions that allow students to explore a concept, develop an understanding of the concept, and finally apply the concept to new situations (Lawson, Abraham, & Renner, 1989). An important feature of POGIL activities is that they "use discipline content to facilitate the development of important process skills including higher-level thinking and the ability to learn and to apply knowledge in new contexts" (Moog & Spencer, 2008, p. 3). The process skills targeted in POGIL classrooms include assessment, communication (oral and written), critical thinking, information processing, management, problem solving, and teamwork.

Although learning cycle activities are designed to foster development of workplace (process) skills in a POGIL classroom, the extent of instructor facilitation is equally important. Previous research examined the role instructor facilitation plays in communication by investigating students' use of argumentation in classroom discourse (Daubenmire et al., 2015;

Kulatunga & Lewis, 2013; Stanford, Moon, Towns, & Cole, 2016). These studies found that the instructors' style of implementation resulted in differences in students' use and quality of argumentation, a key component of effective communication.

Our current study focuses on development of resources to scaffold workplace skills into active learning STEM (science, technology, engineering, and mathematics) classrooms. We report on a single instructor's iterative process for integrating four skills—teamwork, information processing, critical thinking, and problem solving—into an organic chemistry course. These four skills were selected because they represent the skills that students most frequently engage in within science classrooms, and they are emphasized in POGIL activities. Workplace skill definitions provided by the POGIL project (Cole, Lantz, & Ruder, 2018) are depicted in Table 1.

## Participants and setting

This study took place during a two-semester organic chemistry course that met twice a week for 75 minutes and was taught using POGIL pedagogy. Class sizes ranged from 200–250 students in a stadium-seating classroom. For most students, Organic Chemistry I was their first exposure to POGIL. Students in both Organic Chemistry I POGIL and lecture sections could register for the POGIL Organic II course. Therefore, the second-semester course had a number of students new to the POGIL method. For further description on how to implement POGIL in large lecture classrooms, see Ruder and Hunnicutt (2008).

The course materials, written by the first author and course instructor, followed the learning cycle to introduce concepts fundamental to understanding the foundations of organic chemistry. As students completed the activities in groups, they were asked to reflect on different workplace skills via reflector reports and group quizzes. The instructor was supported by six to eight undergraduate teaching assistants (TAs). During class, the TAs were responsible for managing and assisting 10–12 groups of students. The TAs were enrolled in a separate 1.5 credit preceptor course that met once a week with the instructor. TAs are allowed to enroll in this preceptor course for two semesters. The weekly TA meeting consisted of training activities that encompassed facilitation of both content and workplace skills. TAs were also expected to attend class and hold a weekly study session as part of the preceptor course.

## Process for integrating workplace skills into the classroom

An iterative process was used to integrate development of students' workplace skills within the context of learning course content in an organic chemistry classroom. This process began because the instructor recognized a need to explicitly prompt students to help cultivate workplace skills during group work. As shown in Figure 1, three products were continually refined in the attempt to further elicit and assess these skills in the classroom: TA training activities, workplace skill rubrics and course materials. To successfully integrate workplace skills within the context of a large enrollment classroom, it was necessary to enlist the help of TAs. Structured TA training sessions allowed TAs to become familiar with workplace skills and how to help facilitate students' development of these skills. With the help of the TAs a set of rubrics was developed to assess workplace skills during classroom activities. Finally, the course materials (written activities and facilitation prompts) were modified to more effectively encourage students to engage in these skills. Using feedback from both TAs and students, the instructor continues to improve each of these products to cultivate, assess and begin to provide feedback to students on their workplace skill development.

### *TA training activities*

Undergraduate students who had previously completed the two-semester course with A or B grades were recruited as TAs by the course instructor. Potential TAs were required to submit a short application and supply a letter of recommendation from a faculty member. The application consisted of basic information and short essays that allowed the instructor to

**TABLE 1**

**Definitions of workplace skills.**

| Workplace skill | Definition |
|---|---|
| Teamwork | The ability to work with other people to accomplish a common goal. |
| Information processing | The ability to acquire information from a variety of sources. |
| Critical thinking | Exploring a situation, question, or problem to arrive at a hypothesis or conclusion that integrates the available relevant information and therefore can be convincingly justified. |
| Problem solving | Finding a resolution to a situation, question, or problem for which you don't know what to do directly to resolve the issue. |

understand applicants' perception of active learning and their experience with group work. Once accepted, all TAs were required to attend weekly meetings with the course instructor as part of their training. At the weekly meetings TAs worked together to complete class activities prior to facilitating in the classroom. Initial meetings also included discussion of constructivist theory and the design of POGIL activities. To gain experience with the learning cycle, the TAs practiced mapping activity questions according to the learning cycle: exploration, concept invention, or application. During these sessions, the instructor highlighted concepts that are generally problematic for students and prompted TAs to discuss guiding questions that might help students discover the concept. These discussions were critical for helping TAs discover how to facilitate learning by providing guidance rather than simply providing the answer to student questions. At the end of the first semester the TAs' final project was to write a learning cycle activity on a topic of their choosing.

TA training in the second semester focused on facilitation of the targeted workplace skills. While completing activities, TAs reflected on the skills needed to answer the questions. The instructor asked guiding questions to help TAs recognize behaviors that provided evidence of each skill. In addition to weekly meetings, TAs turned in reflection journals that detailed how the TA training influenced their facilitation and what challenges they faced as a TA. This information was used to continuously improve the training provided to current and future TAs.

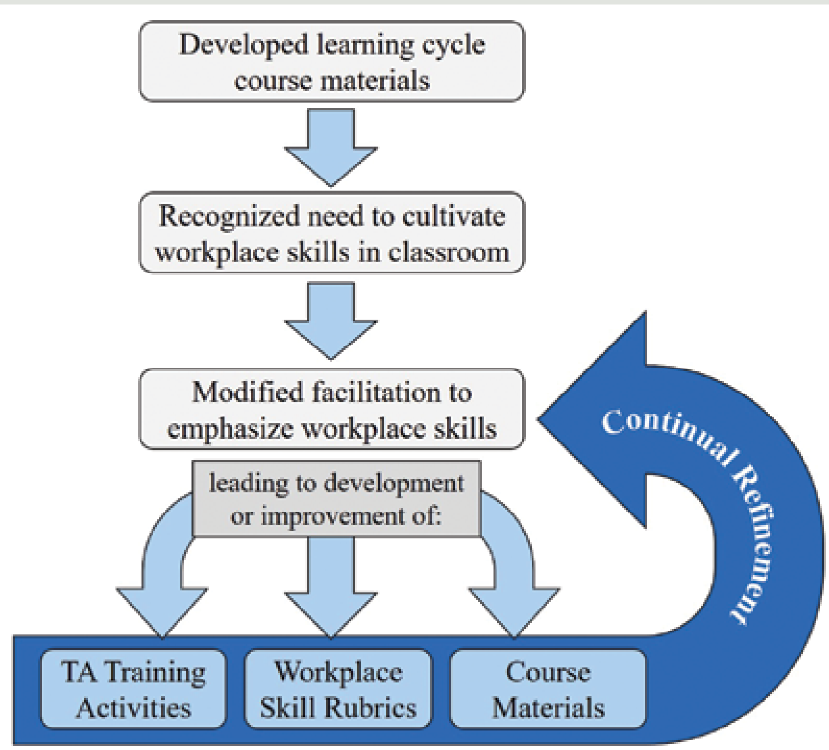
### Workplace skill rubrics

To better assess development of student's workplace skills during in-class group work, our goal was to develop a set of rubrics. Rubrics are useful tools to assess and provide feedback to students; however, to our knowledge, there were no rubrics available to assess workplace skills in the classroom. Initially, discussions at TA meetings focused on identifying the types of student behaviors to expect for each of the targeted workplace skills. Both ideal and nonideal behaviors were considered. For example, a behavior considered ideal when observing information processing would be students evaluating a data table to determine what information is needed to answer a question. On the other hand, a less-ideal behavior would include students neglecting a key piece of information from the table. Discussions of what behaviors to expect for the targeted workplace skill occurred at every TA meeting while working through the content of the activity. After discussing the expected behaviors and then observing these skills during in-class group work, the TAs' final project was to develop workplace skill rubrics.

TAs presented their final version of their rubrics to the preceptor class and discussed their rubric design logic. With multiple TA-drafted rubrics, the instructor could compare different perspectives on student interactions to develop a more versatile and multifaceted rubric. The instructor combined ideas from different rubrics and further modified and refined each rubric to ensure that the language was consistent and aligned with the literature. The final rubrics for each targeted workplace skill are shown in Figure 2. After refinement of the rubrics, they were used in the classroom the following semester to identify evidence of workplace skills. This allowed modifications of both facilitation and written activities to cultivate and further develop the workplace skills.

**FIGURE 1**

**Iterative process used to integrate workplace skills into the classroom.**



TAs used the rubrics during class time to observe different workplace skills. In general, TAs spent around 5–10 minutes per group to observe student behaviors. The completed rubrics and observations of the TAs during student group work were compared with the groups' reflections to gauge the development of workplace skills. In general, the scores assigned by TAs for each group aligned with the group's perspective of their ability for a given skill. For example, a group given high teamwork scores (4 or 5) by the TA noted independently that their group was collaboratively working together and every group member was contributing:

> We all worked together well and contributed equally. We all knew

**FIGURE 2**

**Rubrics to assess students' teamwork, information processing, critical thinking, and problem solving during group work.**

| Teamwork | | |
|---|---|---|
| **1** | **3** | **5** |
| • Group is disjointed<br>• Members not communicating with one another<br>• No collaboration between group members<br>• Group work is conducted independently | • Some discussion among group members but some work independently<br>• One individual may continuously override suggestions of others<br>• Collaboration is sporadic | • Students collaborate on all aspects of the class activity<br>• Students work through each model together<br>• Each member contributes ideas and vocalizes thought processes to arrive at a solution |

| Information Processing | | |
|---|---|---|
| **1** | **3** | **5** |
| • Misinterprets information gathered for task severely or fails to synthesize it<br>• Fails to gather information from appropriate sources at all<br>• Fails to recognize relevance of information from outside sources | • Makes some errors in interpreting and synthesizing outside information gathered<br>• Attempts to gather information from outside sources<br>• Understands relevance of gathered information to some degree | • Accurately interprets information gathered for task with full synthesis of information<br>• Gathers information across variety of sources<br>• Thorough analysis of relevance of information gathered |

| Critical Thinking | | |
|---|---|---|
| **1** | **3** | **5** |
| • Does not explore problem with enough detail to arrive at justifiable conclusion<br>• No logical thought process used to arrive at answer<br>• No integration of information | • Students attempt to examine problem in detail, analyzing the components necessary to arrive at proper conclusion<br>• Assumptions made that are not entirely justifiable and some nonrelevant concepts are included<br>• Answer has some logical basis with evidence | • Problem is thoroughly explored<br>• All information integrated together is relevant and justifiable<br>• Answer shows clearly logical thought pattern with appropriate conclusion |

| Problem Solving | | |
|---|---|---|
| **1** | **3** | **5** |
| • Group members sit and wait for a solution to be presented by instructor<br>• No attempt is made to work through a difficult question<br>• No logical thought pattern has been followed | • The students attempt to come to a strategy to solve a problem<br>• Students start with basic concepts they understand in order to break down question<br>• Students end up going with first strategy selected and disregard other options | • Students analyze the problem carefully, breaking the question apart into basic concepts<br>• Students consider various approaches to the problem, ultimately resulting in the most logical and most sensible solution |

**FIGURE 3**

**Typical cover page for activities highlighting both content knowledge and workplace skills (process objectives). Excerpted from Ruder *(*2015).**

Class Activity 3A Acids and Bases. Part A: Acids/Bases and pKa Values 1

**Class Activity 3A**
**Acids and Bases**
**Part A: Acids/Bases and pKa Values**

**Prior Knowledge:**
Before beginning this activity, students should be familiar with the following concepts:
- Acid/base definitions
- pKa, Ka, Keq
- Formal charge

**Learning Objectives**
**Content Objectives:**
After completing this activity, students should be able to:
- Articulate the differences between the Brönsted-Lowry and the Lewis acid/base definitions.
- Predict acid and base strength based on pKa values and predict the direction of an acid/base reaction.
- Draw curved arrows to depict the mechanism of an acid/base reaction.

**Process Objectives:**
- *Information Processing.* Students interpret acid/base definitions and pKa values to determine the acid/base roles of each reagent and predict acid/base strength.
- *Critical Thinking.* Students analyze acid/base reactions to determine a mechanism and to predict the direction of the reaction based on pKa values.

> certain topics better than others and thus we were able to put our knowledge together to answer the questions. At the end, before answering, we went over our thought process and thus we all learned from each other. (Group 35)

Similarly, a group given lower teamwork scores (3 or less) by the TA wrote reflections that focused on individual participation and less interaction between group members:

> We all divided the work before class. Each one of us focused on one chapter, while still reading other material. It made it easier for us during the quiz. (Group 7)

These reflections demonstrate that students can self-identify behaviors indicative of different workplace skills. Additionally, TAs can record student behaviors on the rubric to provide feedback and determine how effective a behavior is for the development of workplace skills. While evidence of workplace skills can be observed during group work, it is also important to provide students with the necessary scaffolding to help them develop these skills.

## *Course materials*

Scaffolding usage of workplace skills into both classroom facilitation and written POGIL activities allows students to more effectively develop these skills. When writing POGIL activities, the first author was cognizant of following the learning cycle to encompass foundational concepts of organic chemistry. These learning cycle activities allow students to develop information processing, critical thinking, and problem-solving skills by providing the necessary scaffolding for learning content. For example, exploration questions allow students to explore a model (graph, reaction, data, etc.) requiring them to use information processing to interpret information and decide what is relevant. Following exploration, concept invention questions provide students with the opportunity to use critical thinking as they combine information, justify conclusions, and construct a concept. Finally, application questions immerse students in problem-solving strategies to apply newly developed concepts to related situations. In addition to designing activities that follow the learning cycle to naturally develop workplace skills, the first author inserted subtle prompts for teamwork and other skills to help promote their development.

To emphasize the importance of both content and workplace skills, the cover page of each activity details the prerequisite content knowledge and highlights both the content and process learning objectives. Figure 3 depicts an example cover page from Activity 3A, Acids and Bases. Typically, three content learning objectives and one or two workplace (process) skill objectives are emphasized in each activity. In Activity 3A, the workplace skills highlighted are information processing and critical thinking. In POGIL activities, information processing, critical thinking, and problem solving naturally lead into one as a result of the learning cycle. Through facilitation and use of student roles during classwork, other skills such as teamwork, oral communication, and management are developed.

Figure 4 shows an example question from the Acid Base Activity 3A illustrating how workplace skills are readily incorporated into a POGIL activity based on content questions. The questions were "mapped" or coded based on the different workplace skills and their definitions. In this example, as students explore Model 3 and answer Questions 8a-e, the focus is for students to understand and sort the information presented in Model 3. Question 8e also displays teamwork because it prompts students to check with team members before moving on. Although teamwork may be prompted in an activity as shown in 8e, teamwork skills are frequently enforced through instructor facilitation and verbal prompts. Question 8f is considered critical thinking because students must use multiple pieces of information to construct an argument. Students make a claim about the direction of the reaction, and then using the provided data and answers to previous questions, they need to support their answer.

This study used POGIL course materials coupled with effective facilitation to elicit workplace skills into classroom activities without sacrificing content knowledge. Although the POGIL pedagogy is highlighted in this study, any active learning technique could be used to incorporate workplace skills in the classroom. When writing questions for in-class work or homework, instructors should phrase questions in a way that requires students to extract data, construct arguments, and apply knowledge to new situations. This gives students practice developing workplace skills and is also aligned with how scientists conduct research.

## How integration of workplace skills continues to influence classroom

Through the years of refining this course and materials, focus shifted from an initial emphasis on content to a concerted effort to scaffold workplace skills within the context of course content. An explicit focus on development of workplace skills in the classroom was necessary because the written class activities alone did not thoroughly prompt the express development of these skills. Although the course materials naturally led to development of information processing, critical thinking,

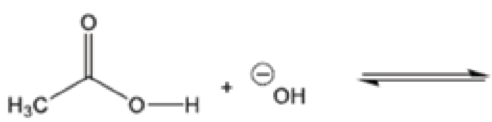
**FIGURE 4**

**Example model and question from activity. Questions have been coded to identify which workplace skill they elicit. Excerpted from Ruder *(*2015).**

**Model 3:** pKa Values of Common Acid/Base Pairs

| Acid (HA) | pKa | Conjugate Base (A⊖) |
|---|---|---|
| HBr | -9 | Br⊖ |
| HCl | -2.2 | Cl⊖ |
| $CH_3CO_2H$ | 4.74 | $CH_3CO_2$⊖ |
| $H_2O$ | 15.7 | HO⊖ |
| $NH_3$ | 33 | $NH_2$⊖ |
| $CH_4$ | ~50 | $CH_3$⊖ |

**8.** A reaction always proceeds from stronger to weaker reagent **(SA + SB → WA + WB)**. Use the pKa values in Model 3 to help answer questions about the following reaction:



**(a)** Using the information from the table in Model 3, the pKa of $CH_3CO_2H$ = ___________ and the pKa of HO⊖ = ___________. Based on these pKa values, label the acid and the base in the above reaction.
**(b)** Describe what happens to the electron pair that the base donates.
**(c)** Describe what happens to the electron pair that the acid accepts.
**(d)** Draw the two products formed above, and label as conjugate acid/conjugate base.
**(e)** Group Check: Does the net charge of the reactants equal the net charge of the products drawn? If not recheck your answer.
**(f)** Predict whether the equilibrium favors the forward or the reverse direction. Explain.

Information Processing

Teamwork

Critical Thinking

and problem solving, the first author began to incorporate additional skills by adding teamwork prompts.

Because the course is taught to a large number of students, it was imperative to also develop TA training that involved instruction on how to facilitate group interactions that foster both the development of content and workplace skills. Discussions of workplace skills helped orient the TAs to understand what to look for and what types of questions to ask the groups. This in turn resulted in the TA training changing from content and basic facilitation to exploring how to recognize workplace skills. To further encourage TAs to reflect on these skills, TA assignments also evolved to having TAs develop materials such as learning cycle activities and workplace skill rubrics.

Classroom facilitation has also been refined to highlight workplace skills. While working through examples during class, the instructor indicates which aspects of each skill are needed to solve a problem and helps focus students' attention. Furthermore, the activities continue to be revised to include more questions that promote advanced critical thinking and metacognition based on observations from student interactions. This preliminary work has resulted in a funded research project that aims to further develop and validate rubrics to assess workplace skills in any STEM discipline or active learning environment (Cole, Lantz, & Ruder, 2016). ■

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## Available resources

Lists of the available POGIL materials can be found at: http://pogil.org/educators/resources/curriculum-materials

Copies of the process skill rubrics can be found at: http://www.elipss.com

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