Title
Guided and Team-Based Learning for Chemical Information Literacy

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Author
Loo, Jeffery L.

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Jeffery L. Loo, MLIS MSc PhD
Chemical Informatics Librarian, Chemistry & Chemical Engineering Library, University of California, Berkeley, 94720, USA

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Abstract

This case study recounts a process of course design, conduct, and evaluation for a single-session chemical information literacy class using guided and team-based learning. This approach incorporates active learning, worked examples, process worksheets, and POGIL elements. The instruction followed an iterative cycle of learning exercises whereby (1) the instructor introduces an information problem or task through a short presentation, (2) student teams collaboratively work through process worksheets that guide them through the technical and analytical tasks of resolving the information problem or task, (3) the instructor serves as a facilitator to address learning needs that arise during the exercise, while student teams analyze and reflect upon the learning activity and concepts, and afterwards, (4) the class engages in a discussion as an opportunity for evaluation, further exploration, and peer instruction. Overall, the guided and team-based learning approach offers opportunities to observe student progress closely and forges a collaborative spirit between students and the instructor for an engaging and rewarding experience.

Introduction

Librarians have adopted a wide range of approaches to information literacy instruction. They include online and in-person methods (Luo, 2010; Williams, 2010; York & Vance, 2009), short "one-shot" approaches (Kenney, 2008), embedded or extended approaches (Ferrer-Vinent & Carello, 2008), and even credit-bearing courses (Mitchell & Hiatt, 2010). Information literacy instruction can be difficult to conduct with any of these instructional approaches but it is particularly challenging in single-session classes. Furthermore, information literacy has a number of complex standards with a wide range of literacies from information access to information ethics (ACRL, 2000). Teaching these standards in light of the time pressure and students' focus on the "end-game" assignment may make the instructional process even more difficult.

A key challenge of this environment is developing and delivering an engaging session that combines practical information literacy skills training, student interaction, and information literacy task practice. Active learning methods may provide opportunities for these types of student engagement, and there is evidence they are more effective than lecture and passive demonstration-based instruction (Michael, 2006; Prince, 2004).

This article documents an approach to delivering chemical information literacy instruction using active learning techniques in a single laboratory session – an approach termed guided and team-based learning. The current literature on single-session information literacy instruction will be reviewed with exploration of the roles of active learning, guided learning experiences, and team-based learning. Afterwards, a case study and model for developing and delivering guided and team-based learning exercises (with particular relevance to chemistry and other science undergraduate disciplines) will be examined.

Background

Challenges of single-session instructional classes

A single-session information literacy class is a common approach for librarians in academic settings. Often times, these sessions are coordinated with specific classes or projects and tend to be focused on specific goals (e.g., identifying literature for a research paper, searching a database, creating a bibliography). While these instructional sessions can be tailored to fit a specific course and students are often required to attend (Rabine & Cardwell, 2000), there are potential drawbacks.

Because the sessions are often short, they may not allow the time to teach a wide range of information literacy skills. It would be difficult for a single session to cover each of the ACRL information literacy competencies – including information problem definition, access, evaluation, and ethical use (ACRL, 2000) – and still be effective in teaching students about the specific course assignment for which the instruction session was designed. Furthermore, research shows difficulties with single-session information literacy instruction for learning retention. Bean and Thomas (2010) found that students retain and recall little from these sessions and Jacobs and Jacobs (2009) observed that “single doses of library instruction” are insufficient for learning the complexities of college-level research. The challenges of a short class are made more complex with the risk of information overload. Parang et al. (2000) report that single-session classes may overwhelm students. Furthermore, single classes offer little time to assess and evaluate student learning styles for tailored instruction and feedback (Gandhi, 2005) and may position librarians as short-term guest lecturers rather than learning and research facilitators (Rabine & Cardwell, 2000). Shorter classes also include the risk of relying on passive learning techniques in order to cover a large amount of content, which may inadvertently lead students to feel that the instruction is "irrelevant to their specific needs" (J. E. Cooper, 1993). Additionally, from anecdotal evidence, it is difficult to build rapport with students, conduct class discussions, and enable intensive exploration in a single class period of limited time.

A review of the literature found three instructional methods that may address these shortcomings. Each method is reviewed and their potential impact on instruction is outlined. The three instructional solutions are active learning methods, guided learning experiences, and team-based learning.

Active learning

Active learning approaches tend to include hands-on activities, exercises, and self-guided tutorials. It often includes elements of reflection, application, self-assessment of progress and knowledge level, and an activity intended to focus attention onto a specific task or skill (Collins & O'Brien, 2003). In cases where a specific skill is very important, active learning may be an effective means of teaching students (Michael, 2006; Prince, 2004). In information literacy, active learning has been shown to increase student motivation and facilitate student learning assessment while providing opportunities for skills practice (Gedeon, 1997). Examples of activity-based instructional tools for information literacy include online instruction modules like those reviewed by Zhang et al. (2007) and activity worksheets as developed by Mitchell and Hiatt (2010).

ACRL recommends active learning techniques in their instructional guidelines for academic libraries, with a particular focus on connecting critical thinking skills with task-based information literacy skills (ACRL Board, 2003). Two other factors for success that ACRL mentions are faculty collaboration and course integration.

Guided learning experiences

Although active learning is regarded as helpful for instruction, there is evidence that active learning activities with only minimal guidance have limited effectiveness (Kirschner, Sweller, & Clark, 2006). Likewise, controlled experimental studies have demonstrated that direct instructional guidance has a positive impact on student learning (Mayer, 2004; Moreno, 2004; Tuovinen & Sweller, 1999). One reason cited for this difference, particularly in information literacy instruction, is the need for feedback and prompting in discovery-based learning environments (Brown & Campione, 1994). Information seeking activities have many avenues and possible outcomes and guidance in these exercises help students avoid misconceptions and unnecessary dead-end activities. This prevents a “sink-or-swim” environment in which students can struggle. Guidance may also avoid an unnecessarily heavy workload and student frustration by reducing the intense cognitive load associated with minimally guided exploration exercises (Clark, Nguyen, & Sweller, 2006; Kirschner, et al., 2006; Tuovinen & Sweller, 1999).

There are a number of guided learning techniques. One method is providing students with worked examples from which they can model future processes. In a worked example, the student sees a “step-by-step demonstration of how to perform a task or how to solve a problem” (Clark, et al., 2006). There is evidence that studying worked examples is an effective instructional strategy in complex problem-solving environments (van Merrienboer, 1997). Sweller and Cooper (1985) and Cooper and Sweller (1987) also found that studying a worked example can help novice students learn algebra better than if they focused on problem-solving exercises with minimal guidance.

Another guided learning technique is process worksheets. These worksheets describe the various stages of problem solving and provide tips and heuristics to help complete each stage (van Merrienboer, 1997). Students follow the worksheets and are able to solve problems on their own with appropriate support and scaffolding, which is “providing support to learners while they engage in activities that are normally beyond their abilities” (Jackson, Stratford, Krajcik, & Soloway, 1996). Nadolski, Kirschner and Van Merrienboer (2005) found that law students who followed process worksheets demonstrated improved learning outcomes over those who learned through self-guided exploration methods.

A third guided learning technique is Process Oriented Guided Inquiry Learning (POGIL). POGIL is an instructional philosophy and methodology documented in its own online community (http://pogil.org) and in a range of publications (D. M. Hanson, 2006; Pienta, Cooper, & Greenbowe, 2005). Moog and Spencer (2008) outline the two aims of POGIL: (a) to have students learn by constructing their own understanding of content and (b) to have students develop learning or meta-literacy skills that include information processing, oral and written communication, critical thinking, problem solving, metacognition, and self-assessment.

In a POGIL learning environment, students work in groups and actively engage in learning activities. Specifically, students follow guided learning worksheets and exercises that take them through cycles of learning that roughly correspond to Bloom’s revised taxonomy (i.e., remember, understand, apply, analyze, evaluate, create) (Krathwohl, 2002). Lawson (1995) delineates POGIL activities into phases of exploration, concept invention or term introduction, and knowledge application. In the exploration phase, students collect or review data to generate hypotheses and then test them in order to come to an explanation or understanding. After students construct their own understanding of the underlying concept, the formal term and definition are introduced – in the phase known as concept invention or term introduction. This contrasts with traditional lectures where concepts are first defined and then examples are given. In the application phase, students apply their learning to new situations and problems.

POGIL instruction emphasizes the development of process skills as well as content skills. It encourages students to employ metacognitive and self-regulation techniques to manage their own learning process. It promotes a student-centered classroom where the focus is on student activity and not instructor presentations. In this paradigm, the instructor is a learning facilitator whose primary roles are to ask probing questions, to guide students in understanding and applying knowledge, and to address misconceptions or misunderstandings (Moog & Spencer, 2008). In a succinct summary by Elmore (1991): "Knowledge results only through active participation in its construction. Students teach each other and they teach the instructor by revealing their understanding of the subject."

Implementing POGIL techniques may take a variety of forms (Farrell, Moog, & Spencer, 1999; D. Hanson & Wolfskill, 2000; Lewis & Lewis, 2005), but there are three common features (Moog & Spencer, 2008). First, students work in small groups of three or four and have assigned roles such as reader, reporter, data calculator, recorder, or manager. Each student may fill one or more roles in the group. In environments where the learning group persists across multiple class sessions or the entire semester, roles are likely to rotate. Second, students complete targeted activities that carefully guide them in learning a concept. These activities usually follow the learning cycle paradigm outlined earlier (i.e., explore, define/understand, apply). Third, the instructor's main role in the classroom is to serve as a student learning facilitator, not lecturer.

While POGIL's foundation is in chemistry instruction, it is not limited to scientific areas. This method has been applied to non-science courses (Hale & Mullen, 2009) as well as undergraduate information literacy instruction (Mitchell & Hiatt, 2010).

Team-based learning

The process of students learning together in teams takes many different forms including team-based learning (Michaelsen & Sweet, 2011), cooperative learning (Johnson, Johnson, & Stanne, 2000), and problem-based learning (Neville, 2009). A common thread among these variations is that students work as part of a group to complete a learning task; they work together and rely on one another through discussion and feedback, division of labor, or specialization to conduct the learning exercise. Consequently, the team solves a problem together and comes to a fuller understanding of the learning concept. Learning through student teams grounds student learning in a peer-centric environment, enables students to learn from fellow students, and allows the distribution of work to enable more complex learning interactions (Mitchell & Hiatt, 2010). From a meta-analysis of 164 studies of cooperative learning methods, Johnson et al. (2000) demonstrated that this technique has a significant positive impact on student achievement. In a chemistry class, students demonstrated higher retention and test scores with cooperative learning as opposed to traditional instructional methods (Dougherty et al., 1995).

Common active learning themes

From the review of selected active learning techniques, there are several common themes. First, active learning seeks to re-define the role of the instructor from lecturer to facilitator. An advantage of this approach is to reclaim class time and to provide direct learning assistance to students for potentially more efficient use of instructional time. Second, these active learning techniques employ scaffolding techniques that are intended to guide students through specific areas of the learning process. Scaffolding provides students with very specific support in ways that lectures and other passive means may not. Finally, active learning techniques aim for students to take control of their own learning process. While this seems like an obvious benefit for mastering content, this approach may also enable students to develop other learning and cognitive skills.

Case study

This case study examines the chemical information literacy instructional sessions for an inorganic synthetic chemistry laboratory class at the University of California, Berkeley, that took place in the fall of 2010 and the fall of 2011 (for a total of four classes taught over the course of two years, with approximately four to ten students per class). The course professor specifically requested that students be given instruction in the discovery and use of scientific literature for preparing laboratory report assignments that were a key part of the course. The learning objectives for the session included familiarizing students with scientific information literature use (e.g., when to cite resources in lab reports, identifying relevant databases, and recognizing citation standards) and skill development for using chemistry databases including both textual and graphical means for searching chemical compounds. Instead of a single hour of class time, the instructor and librarian opted to give a three- to four-hour information literacy class in place of one of the regular laboratory sessions early in the semester. This provided an extended period to cover a wide range of research skills and expanded the time for students to explore research tools with a librarian to facilitate. This case study will examine the instructional framework used in this environment (primarily the guided and team-based learning approach), describe the instructional design process, and reflect on the effectiveness and relevance of this approach for an information literacy class.

Instructional framework

Teaching chemical information research methods is different from information literacy instruction in other disciplines. The complexity of both the search tools and the chemical representation schemes means that instruction on these tools requires more time and is best taught using active learning that offers practice and feedback opportunities. By conducting chemical information literacy instruction in a laboratory class three to four hours long, it is easier to address each of these areas in a single session.

With limited instructional time, it is important that students are motivated to learn specific skills and engage in self-directed learning. To accomplish this, Kenney (2008) suggests that information literacy instruction should have "defined goals and objectives based on a problem that captures student interest." It is helpful to have an instructional framework that demonstrates to students the immediate effect of the information literacy content and skills to their learning and coursework.

Therefore, the class was designed with five principles in mind: (1) balance passive techniques, which are useful for their efficiency in covering instructional topics (e.g., lecture and demonstration), with active techniques (e.g., exploration and task-specific activities); (2) emphasize active methods whenever possible to communicate knowledge and to build student expertise; (3) incorporate team-based learning activities to enable peer student support; (4) provide guided exercises for completing complex tasks and developing the necessary skills; and (5) ensure adequate time for the librarian instructor to support individual as well as group learning. Given the time constraints, it was clear that the full implementation of any single instructional approach (e.g., guided learning experiences, POGIL, team-based learning) would be difficult in a single session, so selected components of various instructional techniques were used in combination.

Instructional design

The class was designed to leverage elements of POGIL, guided learning exercises, and team-based learning. The ultimate goal was for students to gain practical experience with the workflow of using the chemical literature to write lab reports. To learn the necessary information tasks, student teams collaboratively followed worksheets that guided them through problem-solving exercises that offered hands-on practice. Given this approach, some traditional elements of information literacy instruction (such as library service orientation) were excluded to provide more time for practical exercises. To fill this gap in instructional content, the library offers a comprehensive guidebook that orients students to library services.

A 38-page workbook guided the class through the learning process. The workbook was split into a number of exercise worksheets that guide students through the sub-tasks of solving a larger information problem. Borrowing from the POGIL method, the exercises engaged the exploration, concept identification, and application level skills. Example exercises are outlined in Table 1.

Table 1. Example guided and team-based learning exercises

Skills engaged	**Example activity**
Application	• Students retrieve chemical property data in a chemical dictionary. Afterwards, they discuss and analyze their learning with a focus on the value of a tertiary information resource in chemistry (Appendix A, Section 5.1) • After defining and demonstrating Boolean operations, students complete a short exercise identifying the best Boolean operator for a specific search task (Appendix A, Section 7).
Exploration and application	• Students review and study the conventions for drawing chemical structures in a database, and then practice drawing a structure for a particular chemical (Appendix A, Sections 9.1 and 9.2).

Exploration, concept identification, and application	• Students conduct a chemical substructure search and then compare with the results of an exact structure search. Through this comparison, students identify the purpose of a substructure search and come to a definition of this technique (Appendix A, Section 5.1).
Review and application	• Students practice an extensive information task based upon the sub-tasks they learned earlier. In particular, students searched a database for articles on a chemical compound, limited and filtered the result set, and then prepared a citation (Appendix A, Section 11).

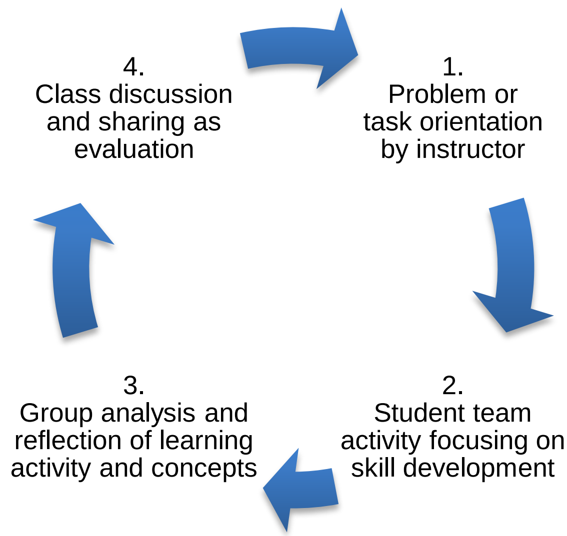
The class followed a cycle of learning activities (as outlined in Figure 1):

1. In a brief presentation, the instructor introduces the information problem or task and provides context by explaining its relevance to the lab report assignment for the class. These lectures are a few minutes long and provide an overview of a central concept or application that underlies an information problem resolution (e.g., find a reference on the first synthesis of a chemical compound in the tertiary literature to provide historical context of the research).
2. Working in teams, students follow process worksheets that guide them stepwise through the technical and analytical tasks to resolve the information problem. Along the way, they respond to targeted fill-in-the-blank and short statement questions. To facilitate student learning, the instructor regularly checks in on student progress and provides targeted support by roaming the classroom from team to team to answer questions and respond to group needs.
3. Students are encouraged to engage in small group discussions to answer broader reflective questions.
4. After the student teams complete an activity, the class re-groups together. The instructor reviews the exercise and students discuss their responses to the short statement and fill-in-the-

blank questions. This is an opportunity for both instructor and student to evaluate class learning and to ensure everyone is on track and that misconceptions are addressed. The class discussions should encourage peer instruction as different student groups share and explain their learning experiences.

5. This cycle then repeats from the beginning with the next information problem or task to be covered.

Figure 1. The class followed a cycle of learning activities



This cycle of student-driven activities will hopefully improve the information literacy learning experience. In minimizing the use of passive instruction methods like lecture segments, students have the opportunity to engage in active learning exercises and to practice critical information tasks. Additionally, active engagement with the instructor will hopefully introduce students to the model of librarians as professional support for learning and research in what King (1993) has termed as the re-branding “from sage on the stage to guide on the side.” But in light of time constraints, the instructor may still need to rely on demonstrations for advanced and complex information tasks.

Creating and teaching using workbooks

The design of a course using worked examples, guided learning techniques, and team-based learning requires careful class planning and development of course materials so that learning activities run smoothly and on schedule. Therefore, developing a workbook of guided exercise worksheets that students may follow along during class is very important.

There were four key steps in creating the workbook: (1) design instructional objectives that are relevant to student needs and interests, (2) explore and map the learning processes and tasks for meeting the instructional objectives, (3) select a learning path for students that delineates activities into student team-led or instructor-led methods, and (4) develop exercise worksheets with stepwise directions that are tested to eliminate unintended ambiguity.

Designing instructional objectives

The instructional objectives were defined as the key information tasks that students would need to complete for their assignment. In this case, the class's laboratory manual was reviewed to parse out the specific tasks that students would encounter (e.g., information discovery, evaluation, and citing in order to substantiate a laboratory report with scientific literature references). The lab manual was helpful because it clearly outlined requirements for literature references with complete examples.

For each task objective, the instructor then carefully documented the workflow necessary for completing the information activity. Based on this workflow, discrete sub-tasks and sets of sub-tasks were identified to refine the learning objective and divide it into smaller manageable activities. For example "find background chemical information" was refined to more specific objectives including "use a tertiary resource to find historical information for an inorganic chemical compound." A key aspect of this refinement process is being selective and explicit in task definition. It is also helpful to organize these task objectives into a hierarchical table of contents for the workbook. This allows the instructor and students to refer to a quick-reference version of the class session for gauging progress and understanding the relationship of the current learning activity to the larger instructional objectives.

Preparing worksheets for learning activities

Taking the specific task objectives identified in the exploration phase, worksheet development involved writing stepwise instructions that guide the learner through the technical and problem-solving steps. For each task, a problem was introduced, and then students followed an approximated POGIL process that included exploration, concept invention/term introduction, and knowledge application. During this process, it makes sense for some tasks to be set up as team exercises, some tasks to be covered as instructor-led demonstrations, and others to be conducted as class discussions. In general, team exercises may work well for core tasks and fundamental activities to encourage skill development and ground student learning. Instructor demonstrations are good for advanced techniques, alternative approaches, and “nice to know” points. These elements are not essential to the core learning objectives and are offered to scaffold students’ self-directed learning after the class. Class discussion time is typically positioned at the end of a learning activity to encourage reflection and peer instruction.

Enabling student-directed learning requires well-planned and detailed worksheets. They provide instruction with explicit procedures and guidance for completing information tasks as they demonstrate key points. A general template for the guided and team-based learning worksheet is outlined in Table 2. The goal of the worksheets is best described by Kenney who noted that "[b]y providing handouts that support the [learning] activity, such as evaluation criteria, and worksheets that enable students to keep a record of their results, students can stay on task and leave with the information they need for their classroom assignment" (Kenney, 2008). It is important that each worksheet activity explores a limited number of new concepts and skills between opportunities for individual reflection and class discussions.

This simplifies the learning process for students and makes it easier for the instructor to coordinate the different paces of student learning.

Table 2: Components of a worksheet for a guided and team-based learning activity

An introductory statement of the information problem or task and its relevance to the class assignment.
Explicit stepwise directions and heuristics that guide students through the constituent steps for problem solving or conducting an information task. These instructions may help students follow along during class, prevent confusion, and serve as a reference guide for completing their assignment independently after the instructional session.
Activity procedures are punctuated with fill-in-the-blank and short statement questions. They provide opportunities for on-the-spot evaluation of student learning and may facilitate team discussion as well.
Each activity is concluded with a summary statement of the learning outcomes that may lead to a class discussion for reviewing the fill-in-the-blank and short statement questions. If an information task is particularly complex and requires lengthy procedures or multiple concepts explained, it is helpful to punctuate the learning activity with discussion breaks to evaluate students and ensure that they are at the same level of comprehension.

In this class, the POGIL worksheet technique was effective in helping students learn chemical substructure searching (Appendix A, Section 5.1). Chemical substructure searching is a complex learning activity that includes both technical and conceptual elements. Substructure searching is analogous to text truncation searching for chemical structures and requires both familiarity with chemical forms and searching syntax. Following the POGIL design process, this worksheet exercise guided students through substructure searching without first defining the concept. Students began by conducting substructure searches followed by exact chemical structure searches, which are analogous to exact phrase searching.

Following the two searches, students compared the results and reflected on the differences. Students were then encouraged to create a hypothesis about what substructure searching does and how it differs from exact structure searching. Finally, student teams discussed their findings to formalize a definition of substructure searching. To confirm comprehension and clear any misunderstandings, the instructor and students discussed their findings and conclusions as a class. Rather than focusing on concept definition and explanation, the worksheet guided students through the discovery, data review, hypothesis formulation, and re-evaluation process with a high level of student success. In this worksheet task, all student teams have succeeded in identifying the differences between the two search types with little instructor guidance. This was confirmed by the instructor's review of the worksheets and the definitions articulated by students during the class discussions.

Conducting the class

Compared to other instructional design approaches, active and POGIL-based learning activities involve considerable preparation. By the time the class occurs, the instructor has carefully defined learning objectives for individual work and group reflection, planned exercise content and sequence, and created a schedule to ensure that the activities fit within the allotted class time. Executing the guided and team-based learning exercises involved a number of elements for success that included preparing students for active learning, monitoring student and group progress to ensure timely completion and synchronicity, and evaluating student progress in order to adjust the path of the class accordingly.

Preparing students for active learning

Preparing students to take the primary instructional role in class took a few minutes at the beginning of the session. The instructor introduced the instructional goals and activities of the session noting in particular the process of team-based completion of guided worksheet exercises along with the motivation and rationale for the learning activities. The class roles and responsibilities were then explained. The instructor facilitates team activities and periodically pulls the class together to review important points and respond to any questions. Students were expected to actively participate in their teams and to discuss and share their learning with fellow classmates.

Contributing to class discussions and engaging in peer instruction may feel awkward to the student at first, particularly if the students are not familiar with one another. Playing a short icebreaker game at the start of the session was useful in building team spirit and encouraged participation throughout the class. Additionally, employing the guided worksheets that follow the learning cycle of information problem or task orientation, hands-on learning activity, group analysis and reflection, and class discussion helped students settle into a routine that became easier for them to contribute in the class. In the first cycle of these activities, it was important to set the tone and rhythm of the class by spending relatively more time to monitor progress and to hold students accountable to the exercise through discussions that evaluated their learning. This first learning activity may build students' confidence and set an expected standard to follow.

In addition to designing the learning activities, structuring classroom equipment was important to preparation. Because students worked in small groups, a modular and pod formation for desks and seating worked best. Lecture hall-style fixed seating or large tables may inhibit close collaboration, particularly in environments where students need to use a specific tool together. Students brought their own notebook computers to class, but backup library computers were also available. Having students use their own computers offered multiple benefits by allowing students to take notes on their personal computer, allowing the instructor to troubleshoot software plug-ins and settings to ensure that students can conduct database searching on their own machine, and allowing students to complete online information literacy tasks themselves in sync with their team members rather than depending on someone else to interact with the database.

Another important element of preparation was ensuring that students were motivated and participatory. The activity focus of the guided and team-based learning approach was an important piece of this as were regular breaks, frequent rotation of activities, and participation at both group and individual levels. Having students work in teams also led to group discussions and close collaborative efforts that cultivated a collegial spirit that further drove participation. Perhaps the most important outcome of the small group work was the fact that students appeared more comfortable speaking before the larger class audience after speaking among their team members first.

Monitoring class progress

Serving as a learning facilitator, the instructor ensured that the class was progressing as needed. It was helpful to outline the number of exercise activities at the beginning of class for a frame of reference along with providing the teams with timing queues (e.g., “Let’s take five more minutes to complete this section!”). Timing was perhaps the most challenging aspect of an activity-driven classroom. The instructor bears the responsibility of ensuring that each group is on task, on time, and that other teams do not fall too far behind. It was sometimes helpful to abandon a planned demonstration or an extended discussion opportunity to facilitate the learning progress of some students. In some situations, encouraging peer instruction might bring students and groups along, and in other cases, it may be necessary to simplify or skip over exercises that are either too complex or do not directly address the core learning objectives.

Evaluating student learning

Compared to a semester-long class, traditional information literacy lectures and demonstrations might not provide substantial opportunities to evaluate student learning. Employing guided and team-based learning exercises offers the unique opportunity for librarians to observe and evaluate student learning while providing targeted guidance. During the activity, the instructor was able to quickly review students' progress by glancing at their worksheet responses. Reserving sufficient time for students to discuss and summarize their learning and providing them with low-barrier methods to ask questions and give feedback were also important. For example, the instructor roamed the classroom and engaged with individual teams to ask how students were doing and to monitor their questions to identify any broader questions that could be addressed to the entire class. Additionally, the summary discussion activities brought the class back together to ensure that a standard level of knowledge was shared across all students, and they provide the instructor with an opportunity to address misconceptions or elaborate on important points.

Another method of evaluation was the assessment of the subsequent reference interactions initiated by students following the information literacy class session. After the reference interaction, the instructor reflected on his perceptions of the questions asked by students, the nature of the assistance requested (e.g., search query formulation, resource identification, resource access), the underlying information need or learning gap, and the elements of chemical information literacy that were important to the given interaction. This approach collected qualitative data on the learning outcomes and experiences of the students. However, it best serves those environments where the instructor is also likely to be the librarian that students contact for assistance.

This method of learning evaluation proved useful for two reasons. First, while it was difficult to conduct comprehensive assessment of learning given the limited instruction time and the lack of access to the class as a whole following the instructional session, students did seek out the instructor for subsequent reference interactions. This provided opportunities to gather observational data on student learning and the information needs they had throughout the semester. Second, while this data gathering method does not yield quantitative data for analysis, it does help in assessing the impact of guided and team-based information literacy training over time and in the context of specific information needs.

The data gathered from these reference observations showed that students tend to ask higher order questions in the one-on-one reference sessions (e.g. interpretation of data from an information resource and finding specialized materials after exhausting the resources discussed in class). This indicates that students who sought additional help grasped the core chemical information literacy skills taught in the class – particularly with the search and retrieval of chemical structures, the ability to frame queries in terms of search platform functionalities, and the ability to recognize and use the information retrieved. Additionally, these reference sessions frequently centered on student research into new and unexpected areas. Several students initiated appointments to explore unique scenarios and exceptions to library procedures (e.g., finding translations of foreign language journals and retrieving print journal articles from the 1800s). These types of reference questions far outweighed procedural and technical questions that were addressed in the worksheets. In comparison, the classes taught by the instructor through traditional lectures and demonstrations generally yielded fewer reference appointments and the questions asked were more often about the basic procedures for retrieving literature.

Supporting information literacy needs following instruction

A key challenge of single-session information literacy instruction is ensuring that students gain the skills needed to be successful in subsequent independent research activities. By employing a highly documented worksheet approach, students have a physical document that they could refer to and work from in the future, which some students even brought to follow-up reference sessions. A side benefit of this approach is that students would already have interacted with the worksheets and made notations to facilitate subsequent interactions with the material.

Evaluation could also be an important foundation for setting post-instruction interactions with students. A follow-up session or a simple survey a few weeks after the information literacy class could provide the opportunity to gather data about student learning outcomes as well as reinforce the notion that librarians are available to students for research assistance. This opportunity might contribute to a rapport between the librarian and the class as a whole so that students feel comfortable to request a reference appointment for advanced and tailored instruction.

In this class thus far, there were not opportunities to conduct this type of evaluation. As is often the case with information literacy instruction, it can be difficult to conduct learning assessments following the class. Many factors, not least of which is the full schedules of students and faculty, can make these types of survey assessments difficult to conduct. For this reason, the instructor focused on an end-of-class informal discussion and reflection exercise and took a post-instruction observational approach to assess learning among students who sought additional reference assistance. In the discussion and reflection activity, the instructor assessed student learning and encouraged future learning by asking students to write down three new things they had learned and three things they felt they needed to explore further. The students then discussed these points as a group with the instructor reinforcing the class objectives and providing context and additional instruction as needed. This was helpful in identifying class exercises that needed refinement and provided an easy-to-implement formative evaluation. In contrast, a more traditional quiz that engaged in summative and quantitative assessments may have assessed a narrower set of skills and may not have provided the same instructional opportunity.

Discussion and Observations

This instructional case recounts a hybrid active learning approach for conducting single-session information literacy instruction for chemistry laboratory classes. The approach attempted to blend active learning, Process Oriented Guided Inquiry Learning (POGIL) techniques, and team-based methods to teach chemical information literacy content and skills. The first attempts at such a blended approach went well, but there are a few areas that would benefit from refinement for future iterations.

First, the instructor found that it can take time to cultivate a collaborative team spirit for the class learning activities. In the four times this class was taught, each group had a different character. In some sessions, students were shyer and non-committal at the beginning of class, but after a few iterations of the exercises they began to answer questions directly, ask tangential questions, self-monitor their progress, and seek help. By the end of the class, the collaborative spirit resulted in increased group discussion participation and peer-based instruction with meta-cognitive activities like learning progress monitoring, time management, and process management. However, this did not occur at a consistent level for each class. Some groups were just more independent than others and did not engage in as much discussion. It is helpful for the instructor to recognize that this exists and to reflect on those more participatory classes in order to identify the characteristics and prompts that foster student collaboration. For example, in one class that had computer and online connectivity difficulties, students had to share machines and the instructor observed that this physical proximity encouraged co-exploration, sharing, and discussion among learners. Future iterations of this class may have two students sharing one computer. Consequently, team members will have to alternate their role as searcher between the exercises for an equal opportunity to gain direct experience with the database or resource.

Second, preparing guided and team-based learning activities is time intensive involving detailed analyses of information activities and the subsequent creation of worksheet activity cycles with stepwise instructions and queues for students. However, this resulted in a replicable and easily measured workbook for instructional delivery. While the worksheets can help guide learning it can be difficult to know in advance how long it will take students to complete them. As a result, it is also important to prepare for the timing of class activities and to have plans for skipping over activities if required. Prior to conducting the class, it is helpful to have another librarian or a student to complete the worksheets for feedback on the activity appropriateness, gaps in instruction, and timing needs.

Third, while the instructional sessions in this case proved rewarding, the guided and team-based learning approach may not always be productive. The three- to four-hour sessions of this class afforded a time-intensive approach, but this period is much longer than many information literacy instruction opportunities allow. While the worksheet process helps students gain experience with information systems and develop team-based learning skills, it may also delay the pace of instruction. Another complicating factor is the content itself. Worksheet or POGIL methods are a good and convenient fit for technical skills or process-focused content, but might not be ideal for other topics. For example, if the information literacy elements being taught are more abstract (e.g., ethical use of information, plagiarism, or information freedom issues), process-oriented worksheets may not be as effective as other means like discussion-based activities.

The ability to scale is a final complicating issue. While a worksheet-driven and team-based approach may allow the instructor to provide more intensive learning support for students, the experience of this class showed that monitoring multiple groups and coordinating large class discussions could be a difficult skill to master. Therefore, multiple instructors or teaching support would be very helpful in larger classes.

The guided and team-based learning approach includes features that may have wider impact for information literacy instruction in subjects and disciplines beyond chemistry. For example, this approach emphasizes collaborative learning techniques to encourage students to adopt multiple roles (e.g., learner, peer instructor, speaker) and to provide opportunities for the instructor to work with students in both individual and group settings. This is accomplished by engaging with information literacy tasks from a problem solving perspective, enabling student discovery as a key part of the learning process, and emphasizing class time for active practice rather than passive observation. And in minimizing lectures and employing team-based problem solving that is carefully guided by worksheets, students are able to adopt peer instruction and teamwork roles that foster collaborative discovery and create a learning network that may persist outside the classroom. Additionally, by serving as facilitators rather than lecturers, class instructors are able to observe student progress more closely and provide direct support to individuals and groups as needed. Furthermore, it can be difficult in a single-session instructional environment to help students connect specific information literacy tasks with higher-level information analysis, understanding, and application activities. By dividing the learning into problem-based units that involve discovery, analysis, and problem resolution, the guided and team-based learning approach provides a framework to facilitate this higher-order learning. However, this manner of instruction is easier to conduct where there are explicit directions for base level tasks. Explicit instructions may reduce uncertainty, enable faster acquisition of task literacies, and support repetition and replication following the class (Clark, et al., 2006; Kirschner, et al., 2006; Tuovinen & Sweller, 1999). These elements combine to create an efficient scaffold to support complex problem solving both during and after classroom time.

Next steps for the guided and team-based learning approach are to translate the techniques to different learning settings. Variations in the audience, the subject-specific information literacy skills being taught, the modes of delivery, and the level of learning support and preparation could all be explored. This chemical information literacy class was directed at upper division undergraduate students who have already experienced a wide range of laboratory-based classes. Consequently, the students may have gained team-based problem-solving skills to facilitate this style of learning. It would be interesting to observe how the guided and team-based learning approach would apply to lower division students or to larger classes where team dynamics may be difficult to coordinate. Additionally, the class employed guided worksheets to facilitate learning of technical and process-oriented skills. Similar worksheet activities might be developed for students learning abstract information literacy concepts, perhaps by preparing student teams to formulate their thoughts in order to facilitate a group discussion. And as college instruction increasingly moves to online modes of delivery, there could be exploration of the worksheet approach for independent self-directed learning or for use by teams in distributed online environments. This may require more multimedia like video lectures and demonstrations to support and engage learning. Finally, the class instruction took place over a three- to four-hour period, allowing for extended exploration of the learning concepts. Identifying ways to condense this style of instruction to a one-hour period would be beneficial. This may require self-instruction and student preparation outside of class time, and the class may need to focus on fewer instructional objectives. When exploring these variations, it will be important to identify the best practices and to evaluate the impact on student experience, workload, and learning outcomes to ensure that they remain positive and manageable.

Conclusion

This case recounts a process of course design, conduct, and evaluation for a single-session chemical information literacy class using guided and team-based learning that incorporates active learning, worked examples, process worksheets, and POGIL elements. These methods have been employed in other information literacy and science course environments and in semester-long classes, but they have also been effective methods for delivering this extended single-session class.

The instruction employed an iterative series of learning exercises that followed a cycle: (1) the instructor introduced an information task or problem through a short presentation, (2) student teams worked through process worksheets that guided them through the technical and analytical tasks of resolving the information problem, (3) the instructor served as a facilitator to check in with groups in order to address learning needs that arise during the exercise, and afterwards, (4) the class engaged in discussions of the exercise as an opportunity for evaluation, further exploration, and peer instruction.

While the guided and team-based learning approach was a valuable instructional paradigm for this class, there were some challenges. In particular, there was a need for preparing, monitoring, and supporting students to ensure participation, a positive team climate, and collaborative engagement in the learning activities. Careful planning for the class with clear worked examples and worksheets also required extensive preparation time. Furthermore, this approach has not been tested for the instruction of abstract information literacy concepts, which may require more complex and nuanced exercises and discussions.

There were a number of key advantages to the guided and team-based learning approach. Students gained practical hands-on experience in a guided fashion with worksheets that then supported their post-instruction assignments. The ability to re-use these workbooks in later instructional sessions and by other instructors was invaluable for class preparation. This instructional approach was also able to address some of the restrictions of single-session information literacy instruction by providing the structure and procedures for incorporating active learning, discussion exercises, and evaluation of student learning. In addition, by serving as facilitator for the learning activities, the instructor may find a way to provide personalized research assistance and support for student learning during the instructional class. Finally, the ability to engage with students one-on-one through an activity-based class proved to be a rewarding experience that forged a collaborative spirit between students and the instructor. This allowed the instructor to observe student progress closely and helped build a relationship that facilitated reference interactions throughout the semester.

Appendix A

Supplementary file in the attached chem108workbook2012.pdf.

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