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Scaffolded Semi-Flipped General Chemistry Designed To Support Rural Students' Learning

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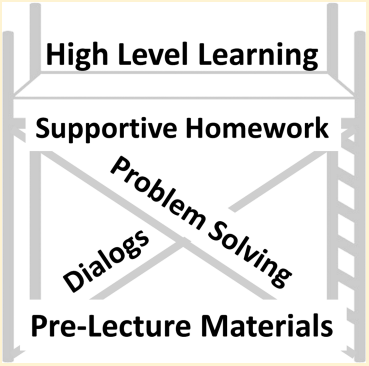
ABSTRACT: Students who lack academic maturity can sometimes feel overwhelmed in a fully flipped classroom. Here an alternative, the Semi-Flipped method, is discussed. Rural students, who face unique challenges in transitioning from high school learning to college-level learning, can particularly profit from the use of the Semi-Flipped method in the General Chemistry classroom. This method brings together preparation before class, active learning in class, and a supportive homework system, and it appears to have significant benefits both for students and for the instructor.



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The Flipped Classroom approach, which has also been known by other names such as "inverted teaching", has grown in popularity in recent years.[1−4] Many models exist, but the heart of the approach is to move direct instruction from the group learning space to the individual learning space.[5] This allows the classroom sessions to be focused on student-centered learning[6] in which students spend time working on problems, advancing conceptual understanding of challenging topics, and actively engaging with the material as opposed to being passive recipients of material from the lecturer.

A number of recent publications have investigated the success of the flipped classroom approach. Weaver and Sturtevant[7] reported that the conjunction of a flipped classroom (lecture content delivered as videos accompanied by an online quiz) and an in-class active learning approach can improve students' ACS General Chemistry Exam scores by almost one standard deviation compared with traditional lecture. Similarly, Hibbard, Sung, and Wells[8] reported that a flipped general chemistry sequence for majors featuring textbook readings tied to instructor-narrated lectures online and extensive in-class problem solving activities also led to enhanced performance on the ACS standardized exam.

Ryan and Reid[9] focused on a different measure of success than the ACS exam. They flipped a second-semester general chemistry course by delivering the lecture content as voice-over PowerPoint videos and by focusing in-class time on problem solving with occasional demonstrations or "microlectures" given on specific topics. They found that exam performance, when compared to a control lecture classroom, was statistically improved for the bottom third of students in the class and that there was a significant decrease in D's, F's, and withdrawals (DFWs).

A number of reviews of the flipped approach have also been published recently. Seery[10] reviewed the literature for information on flipping the chemistry classroom and identified a number of similarities among differing approaches to flipped pedagogy. He found the predominant method of delivery of preclass instruction to be PowerPoint recordings with voice narration, known as screencasts, and he noted that the flipped delivery allowed significantly more time for in-class problem solving in groups. He reported that many of the studies he reviewed showed a shifted grade distribution, with flipped classrooms reducing DFWs. DeLozier and Rhodes[11] reviewed the literature on flipped classroom approaches across disciplines and sought to evaluate the quality of activities and practices used in the flipped classroom. They suggested that any advantage gained by a flipped classroom approach comes not from providing lectures outside the classroom but instead from releasing class time for active learning. They emphasized that instructors sought to integrate activities that engage various cognitive processes, and they noted that various forces operate to influence student learning. Finally, Schell and Mazur[12] completed a thorough review of flipped approaches toward teaching chemistry. In their work, they indicated three main ideas that educators must embrace when adopting a flipped classroom: prior knowledge is required on the students' part to scaffold deeper learning, students learn best when they are engaged with the material, and student learning does not cease when the class ends. They provided several basic principles to guide instructors in the process of flipping their classes. They

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further described Peer Instruction[13] and its utilization in a flipped chemistry classroom.

While working with the students at Ohio University Eastern (OUE), I became interested in implementing a flipped general chemistry sequence but had concerns about applying the fully flipped model to my student population. Whereas the body of work cited above makes the flipped approach appear, at first glance, to be well-suited for engaging all students, some limitations in the literature must be noted. Weaver and Sturtevant[7] noted that the students in their study were chemistry majors at Purdue University with high Math SAT scores and were likely to be motivated to learn chemistry. The class studied by Hibbard, Sung, and Wells[8] was also one for majors. Finally, whereas Seery's review[10] noted that student opinions were overwhelmingly in support of the flipped approach, out of the 12 studies reported, only three were of general chemistry courses (the other courses were upper-level courses like organic chemistry or spectroscopy). Moreover, of those three, only one took place at an open-enrollment institution.

Along with the limitations in the flipped literature, several criticisms of a fully flipped classroom were also found. Hibbard, Sung, and Wells[8] noted that a common criticism of the flipped approach was that students would prefer a more traditional lecture. They further found that the flipped format requires students to take ownership of their learning and rewards those who are motivated to learn: the students who mastered time management and organizational skills were the ones able to take full advantage of the methodology. Ryan and Reid,[9] at Marquette University, noted that a minority of students, despite self-selecting into the flipped class, never embraced the flipped format. The flipped model has also been shown to "require an adjusting period" and to be "overwhelming".[14] Students have even reported that the "flipped structure hindered their learning and suggested that the flipped classroom was the reason for lower than expected grades" at an open-enrollment college.[15]

The limitations in the literature and criticisms mentioned above seemed to suggest that the flipped model requires a level of maturity and ownership of the material that OUE students do not readily have when they encounter general chemistry. OUE is a Rural, Fringe[16] open-enrollment regional campus in the Appalachian region of the Upper Ohio Valley. The freshman class in academic year 2015−2016 had an average composite ACT score of 20 and an average Math ACT score of 19, both of which are below the national average.[17] Because of these facts and because rural students are particularly likely to become alienated from finishing their college career if they perceive the college environment as overtaxing or as one in which they do not believe that they can succeed,[18] the fully flipped method was not adopted. A new approach, dubbed the "Semi-Flipped" model, was instead designed for use at OUE. This model modifies the fully flipped classroom approach in ways intended to make it better-suited to bridging the transition from high school to college for students who face challenges similar to those at OUE, including many rural students.

The Semi-Flipped model supports the education of rural students in numerous ways. Mentoring has been shown to significantly impact the educational attainment of such students.[19] The model (described below) involves substantial mentoring by the instructor. The instructor is encouraging, has high expectations, and actively works with the students so that they can be successful in the classroom. Also, rural students who live with their parents often struggle with extensive amounts of homework because their parents feel strongly that after-school time should be spent on household duties,[20] extracurricular activities, or jobs.[21] The homework assigned in the Semi-Flipped model is designed to require significantly less time and independent synthesis of ideas than fully flipped assignments, freeing up students to maintain their connection to their families while still holding them to high standards of education. Moreover, rural students can become overwhelmed and lose hope when they do not believe that success is achievable.[22] This model allows many different opportunities for students to gain confidence in their ability to be successful, thus alleviating hopelessness and allowing students to focus on learning. Finally, scaffolding (in which the instructor guides students from lower-level to higher-level thinking skills) has been shown to be especially powerful for rural students.[23] For example, Appalachian students learn best when instructors help them shift from informal to formal speech and model appropriate behaviors and conversations.[24] Scaffolding is an important component of the Semi-Flipped model, and it appears during the classroom activities and in the homework assignments. Because of these features, the Semi-Flipped model could be an ideal bridge for students to transition into the college atmosphere and to learn to become successful autonomous learners without the overwhelming responsibility and academic maturity that may be required to be successful in a fully flipped classroom.

DESCRIPTION OF THE COURSE

Each semester of general chemistry taught at OUE is a four credit-hour course that encompasses both the lecture and laboratory. A typical class consists of approximately 20−24 students, and the instructor is the same for both lecture and lab; there are no teaching assistants. The lecture portion of the class meets twice a week for 80 minutes. OUE does not offer a major in chemistry. Two main groups of students take the general chemistry course sequence: high school students taking the course for both high school and college credit and students wishing to major in biological or health science fields. The Semi-Flipped method was implemented in the 2014−2015 academic year and continued again in 2015−2016. The demographics of the two years were similar. Approximately half the class (55% in 2014−2015 and 46% in 2015−2016) were high-school-option students, and about half the class (52% in 2014−2015 and 50% in 2015−2016) had the class rank of Freshman. The class was predominantly male in 2014−2015 (68%) but more evenly split in 2015−2016 (54%).

DESCRIPTION OF PRECLASS MATERIALS

Unlike in a typical fully flipped classroom, students do not watch videos before class. (It should be mentioned that while there are more ways to flip a class than to assign videos or screencasts, screencasts appear to be the most popular way to flip a class.[10]) Instead, students in the Semi-Flipped class read assigned textbook sections before each class period. These sections are outlined in the course calendar and syllabus that is distributed on the first day. To incentivize preparation, students can complete an online extra-credit activity (a McGraw-Hill LearnSmart flashcard module) that assesses student comprehension.

LearnSmart is an adaptive technology that allows students to build their learning in an individualized manner.[25] It consists of a series of "flashcards" that ask questions directly related to the

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assigned book section. Students assign a confidence rating to each flashcard answer, and LearnSmart uses this information to adjust the student's learning path. The most attractive feature of LearnSmart for preclass preparation and utilization in the Semi-Flipped method is the option that allows students to "Read About This". This option opens up the textbook as an e-book, and the passage that pertains to the question is highlighted. Highlighting key information focuses students' attention onto the relevant material in the context of their textbook as a whole. Repeated use of this feature may help students acquire more effective reading skills by showing them how to appropriately focus their attention and use their textbooks to locate information more effectively, but more importantly, it shows students how useful their textbooks can be. Effective reading skills and utilization of texts may help students transition into independent learners.[26] The modules are designed to take no more than about 30 min for each class preparation, and they count toward extra credit for the course.

DESCRIPTION OF IN-CLASS ACTIVITIES

As in a flipped classroom, the Semi-Flipped class period begins with students engaging in hands-on problem solving that reflects their understanding of key information. This is dubbed "a look back before a step forward". The "look back" portion involves three or four problems on which students begin to work as soon as they arrive. These problems reinforce material covered in the previous class period and are higher up in Bloom's taxonomy;[27] they require students to synthesize concepts learned in the previous class and apply those concepts to difficult problems. This formative assessment allows the students to test their knowledge and mastery of the material while simultaneously providing the instructor with insight as to how well they understand the concepts. Students are encouraged to work in pairs to solve these problems, and the instructor circulates the room helping the groups. This activity can go on for as long as 15 min, and it allows the instructor to pinpoint and clear up misconceptions or adjust for any lack of content knowledge on the spot. If some groups make similar mistakes or have the same misconception, attention is called to the front of the room and a mini-lecture is given to clear up conceptual problems. After most of the students have completed the "look back", a few minutes are spent going through the answers for those students that might still be struggling. Students that need more time to tackle the problems are encouraged to come to office hours or to talk more with their peers outside of class time.

After the "look back" problems are complete, the "step forward" portion takes up the remainder of the class. The step forward portion alternates between two types of segments: "lecture segments" of about 10−15 min duration and periods of active learning of about 5−10 min. The lecture segments used in the Semi-Flipped model differ significantly from a fully flipped classroom in that they are heavily influenced by Gutenberg[28,29] and Mazur.[30] The lecture segments rely on a dialogue between the instructor and the students, and they help to scaffold student learning and critical thinking by modeling appropriate behaviors such as detailed analysis of information given in a problem or extension of a concept to different examples. The instructor acts as a "coach" and cooperates with the students to assist them in constructing their understanding by making their thinking visible to the students so that students can learn how to see concepts as an expert does. The topic for the day is constructed by questioning rather than by telling the students about the material. Information is elicited from the students, and connections are drawn between what the students already know or have learned for themselves in the preclass activities while building up the new material for the day. Frequently, students will speak out to say, "Ahh, now that makes sense. I didn't quite understand what the book meant about that." Questions that students pose are usually turned toward other students who can then answer the questions and a discussion can take place. Students spend significant quantities of time thinking about the material before either answering a question or posing a question themselves. This helps build up students' confidence in themselves and their ability to succeed, which is a powerful motivator for students who may typically struggle with difficult material.

The active learning segments, which are similar to the problem solving session of a typical flipped classroom, consist of problems that apply the concepts covered in the lecture segment just prior. These problems function as a "Concept Check"[6] and allow students to practice their problem solving abilities and obtain feedback about their mastery immediately. These problems tend to be lower in Bloom's taxonomy than the "look back" problems and focus on scaffolding the material to be learned. For example, a problem asking the student to calculate the pH of a certain molarity solution of acetic acid might be broken down into three or four "subquestions" that guide the student to determine the balanced equilibrium equation, to determine the K_a given the pK_a, and finally to calculate the pH. Deconstruction of the problem in this manner helps students build up their understanding by connecting old information to new concepts as well as helping them feel like they can succeed in solving problems by giving them more manageable bits.

As in the "look back", students are encouraged to work in small groups during the active learning segments. Since peer instruction has been shown to be effective in improving student learning outcomes,[31] the instructor actively fosters interaction between the students early in the semester. For example, a student who has already reached the correct answer is encouraged to explain his or her reasoning to a struggling student, and two students who have different answers are paired together so that each may argue for his or her conclusion. Though students sometimes initially resist such peer instruction, it is ingrained early in the semester and therefore becomes the culture of the classroom, which ensures that peer instruction is constantly occurring. This makes strong encouragement by the instructor unnecessary later in the semester except as a reminder.

DESCRIPTION OF HOMEWORK

Homework assignments consist of novel problems designed to aid students in internalizing the materials and concepts learned in the classroom. Homework problems and due dates are included in the syllabus so that students can begin working on their homework as soon as they want, thereby learning to prioritize their time. The homework is divided by chapter and is due 1 week after the material is covered in class. Connect, McGraw-Hill's online homework system, is used. Connect gives individualized help on each question by offering different options to the student. These options allow students to complete the homework in a scaffolded manner, building up their understanding one piece at a time. "Read About This" directly opens up the e-book with the relevant passage highlighted, which may help students learn to find relevant

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information in their textbooks. "Guided Solution" breaks the problem down into manageable steps, in a way that is similar to the deconstruction technique utilized in the classroom. "Guided Solution" does not simply do the problem for the student, but rather asks for further input in pieces. No credit is given if a student simply completes the guided solution, but credit is given when a similar problem is successfully completed using the "Try Another" option.

All of the above features of Connect, many of which are likely shared by other online homework systems, help to bolster students' confidence in their ability to learn. Students get multiple attempts at each problem, which ensures that students take the time to build up their understanding without the concern or anxiety associated with obtaining a high grade. Frequent low-stakes assessments allow the students to focus on learning the material rather than just getting the right answer.

INFORMAL ASSESSMENT/OBSERVATIONS

The Semi-Flipped model of teaching general chemistry at OUE has not yet been formally assessed to determine whether it is more effective than a traditional lecture course or fully flipped course. That being said, some positive outcomes have been observed. A moderate segment of the class completes the preclass LearnSmart activity (about 33% of the class completes at least 80% of the assignments per semester). This segment of the class scored higher on the final exam (from an average of 1% higher in Fall 2014 to 14% higher in Fall 2015, with different exams used each year) as well as higher in the class as a whole (from an average of 5% higher in Fall 2014 to 18% higher in Spring 2015). No student in any semester who completed the preclass activities received less than a B in the class as a whole. Though the preclass activities were for extra credit, such that typically strong students may have self-selected into completing them, these data are at least suggestive of the efficacy of the preclass aspect of the Semi-Flipped model.

Anecdotally, students appear to engage well with this style of teaching and have shown appreciation for how the techniques used in the class (coming to class prepared, analyzing problems as an expert would, and thinking through material directly after covering it) are useful in other courses as well. For example, various students have commented that they never realized how important the textbook was and that they will start using their textbooks more in their other classes. End-of-semester student course evaluations have typically been very high (an average of 4.84 out of 5, with the campus mean for the same period being 4.40) when the Semi-Flipped model has been utilized, and some positive comments have been recorded for both the LearnSmart preclass materials and the Connect homework system ("Fan of McGraw Hill Connect" and "I like the LearnSmart" were recorded). Students typically say that they have no suggestions for improvement, "keep doing what you are doing", or "very challenging class, but she makes sure you learn the material". One even commented that "I hope she continues her style of teaching. It is very effective for me." More important to note, however, is the absence of negative comments about the Semi-Flipped pedagogy in the course evaluations. Despite the question "What suggestions do you have for improvement of the instructor (e.g., method, approach, attitude) or of the course (content, texts, etc.)?", very few negative comments are recorded. The only real complaint about the Semi-Flipped pedagogy itself, which was recorded only three times across all four academic semesters, is that the LearnSmart preclass activity should be due after class or in bulk before the final exam so that students "do not have to guess". This suggests that a small minority of students failed to grasp that the point of the LearnSmart activity was to encourage them to come to class prepared.

The Semi-Flipped model also has significant benefits for the instructor compared with a traditional lecture environment. Student verbalization of their thought processes during the active learning segments and during dialogue in the lecture segments enhances awareness of how students understand the material. Furthermore, when misconceptions in students' understanding become evident, the method allows for the addition of on-the-spot "lecture segments" so that those misconceptions can be addressed as they are forming rather than later when they become evident on a high-stakes summative exam. Also, utilization of the McGraw-Hill resources as preclass materials makes the Semi-Flipped model somewhat easier to implement than the typical fully flipped model, which involves building up a video library.

The instructor also learns significant information about each student during the active learning segments and can therefore tailor the learning experience for the particular population of students each semester. Though this benefit is not unique to the Semi-Flipped model, it is particularly important for rural students, who benefit greatly from a significant mentoring relationship. For example, some of this semester's students want to attend medical school. Knowing this, the instructor has brought in more medically relevant examples and problems to show how general chemistry applies to that field. In a previous semester, some students were interested in physics as a possible career path. The active learning segments in that semester focused on the physical principles behind different general chemistry concepts. Students enjoy this direct application to their desired career paths.

Finally, the Semi-Flipped model fosters relationship-building between the instructor and the students and among the students themselves. Because the lecture segments are conducted as a dialogue between the instructor and the class as a whole, students are able to communicate directly with the instructor in each class period. Students quickly realize that the instructor is a guide through the material, and a trusting relationship is built up. Similarly, because the lecture segments are with the class as a whole, the students can develop relationships with every other classmate, not just those assigned to problem solving groups or whom they happen to sit next to on a given day. These student relationships spill over into the laboratory segment of the class as well as carrying on through other courses the students share.

CONCLUSIONS

The Semi-Flipped model utilized to teach general chemistry at OUE, a rural, open-enrollment, Appalachian school, appears to have some advantages over the fully flipped model for the types of students that attend OUE. The Semi-Flipped method may help ease students into becoming autonomous learners through its significant mentoring component, decreased workload outside of class, and extensive instructor guidance compared with a fully flipped classroom. Class time is alternated between dialogues with the entire class and active learning in small groups. Students appear to make learning gains with this method, and it also has significant benefits for the instructor.

In the future, it would be desirable to increase the percentage of students who complete the preclass assignments. Changing the preclass assignments from being optional extra-credit

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opportunities to being graded assignments would increase participation and could benefit all students in the class. Furthermore, it is hoped that a formal assessment can be undertaken to examine the impacts of the Semi-Flipped model on student learning. Utilization of the end-of-semester ACS National Exams starting next year will provide data that could be used in a formal assessment as well as a means to ensure that the quality of the education received at OUE is comparable to the quality of education received at other institutions. There is every expectation that students at OUE will be able to complete the ACS National Exams at or above national averages.

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Notes

The author declares no competing financial interest.

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