Chapter 20

Using Structured Study Groups to Create Chemistry Honors Sections

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The University of Michigan is a large, public, Research I institution, founded in 1817 in Detroit and relocated to Ann Arbor in 1837. Over 37,000 students on the Ann Arbor campus are enrolled in 19 different colleges, schools, and divisions, including nearly 17,000 enrolled in the largest of these units, the College of Literature, Science, and the Arts, in which the Department of Chemistry is located.

In 1994, the Department of Chemistry introduced an elective honors option, called Structured Study Groups (SSG), within both terms of "Structure and Reactivity," our 1,000-student first-year contemporary organic chemistry course. Students who wish to take this course for honors credit enroll in the SSG option in addition to taking the regular lecture, recitation, and laboratory portions of the course. The SSGs meet two evening hours per week in collaborative learning sessions led by junior or senior undergraduate student leaders.

We developed this modified supplemental instruction option in lieu of a separate honors section of the course because we felt that first-term students could not judge whether taking an honors section of organic chemistry is appropriate for them. Under our format, students can experiment with taking the course for honors credit for three weeks and then drop the SSG sessions if they find them too difficult. Because SSG honors students take the same recitation sections, labs, and exams as nonSSG students, coursework for honors and nonhonors credits can be compared easily. In addition, an SSG honors option saves a faculty teaching assignment that otherwise would be required for a separate honors section. Finally, the SSG option is not restricted to students in the honors program. Any student who elects and completes the SSG option is awarded honors credit.

Approximately 18% of the students in the first-term course, and 16% in the second-term course, enroll in the SSG honors option. About half of second-semester students enrolled in SSGs are in the regular 800-person course; the rest are in a separate, more intensive version of the course where everyone participates in SSGs. Table 20.1 summarizes the scope of the SSG program.

Model

The concept of reciprocal teaching (Brown & Palincsar, 1989; Palincsar & Brown, 1984;) and the power of explanatory knowledge (Coleman, 1998; Coleman, Brown, & Rivkin, 1997) have informed our design of the SSG model. In reciprocal teaching, instructional tasks are designed by studying the strategies used by successful learners and implementing these to guide novices' learning. In an explanatory framework, tests are seen as an opportunity for students to teach us, to demonstrate their understanding by explaining their ideas, and it proposes that students need opportunities to practice and develop teaching skills before their teaching performance is tested. Research on explanatory knowledge concludes that students need to reflect on their learning and develop interpersonal com-

Table 20.1 The Scope of the University of Michigan SSG Program (1998–1999)

Term	Total Enrollment	SSG Enrollment	No. Sections (Leaders)
Structure/Reactivity I (Chem 210)	1,000	175	12
Structure/Reactivity II (Chem 215)	800	175	12
Structure/Reactivity II (Intensive)	65	65	5

munication skills as a part of the learning process. This reflection and skill development will help them understand that true learning comes from discussing the basis for one's answers and conclusions rather than memorizing the answers (Chambers & Abrami, 1991). Effective teaching also involves viewing students' answers as a step in the learning process instead of as being correct or incorrect. An effective teacher can look at students' answers from both the student and teacher perspectives and focus on the assumptions that led to those answers. The challenge that then arises is reconciling inconsistencies between student and teacher perspectives. SSG leaders provide a bridge to help with this reconciliation.

SSG Leader Selection and Training

SSG leaders are juniors and seniors who demonstrated teaching skills when they were SSG students. Deliberately following the analogy of moving students who demonstrate research potential in laboratory courses and to higher level work, SSG tasks permit students to demonstrate their teaching potential with the idea that they might become SSG leaders. SSG leaders identify prospective future leaders from among their students and justify their choices to the faculty coordinator. Identified students submit essays to the coordinator as part of the selection process for SSG leaders. Leaders are not necessarily chemistry majors; of 36 student leaders from 1994 to 1999, 23 have been majors in chemistry, one in biochemistry, three in biology, and nine in cellular and molecular biology.

As former SSG participants, SSG leaders begin with a strong sense of the program. SSG leaders attend weekly lunchtime meetings with the faculty coordinator to reflect on their teaching, anticipate teaching issues, and determine the evaluation criteria for the week. Each week a different leader leads a discussion on teaching and learning, and then records and distributes the outcomes and recommendations for the group. Leaders continue to discuss teaching issues throughout the week on the SSG leaders' listserv.

SSG Leaders in Chemistry 210 ("Structure and Reactivity I")

Because SSG sessions are for honors credit, leaders must go beyond leading group work with problem sets or delivering extra content in a didactic manner. SSG sessions follow a detailed curriculum that encourages discussion and explanation activities that lead to deep mastery of organic chemistry. SSG sessions and homework assignments involve a number of activities that build on each other. In the first session for example, SSG leaders 1) have students go to the blackboard to teach one another how to decode line formulas, 2) take them to the library to explore chemistry journals, and 3) present a short lecture on proper citation format.

For the subsequent homework assignment, SSG leaders have students apply the concepts to new material using a creative task. For their first assignment for example, leaders ask students to pick a molecule with 10-13 carbon atoms from a chemistry journal, construct five new molecules with the same formula, rank the molecules based on selected properties (e.g., magnitude of dipole moment, boiling point, and solubility), and write out rationales for their rankings. The student work for this assignment must include a statement putting the journal article into context, a copy of the journal page from which the example came, and a properly formatted citation. In other assignments, leaders ask students to format an appropriate quiz problem from the new material.

The next SSG session builds on the homework assignment. Students must submit one copy of their homework to their leader and distribute the rest to their classmates for one or two rounds of peer review. SSG leaders create a set of review questions, which for the first assignment might address whether the molecules fit the prescribed criteria, whether the format and information are appropriate to the class level, and whether the citation is formatted correctly. Peer review is a time of in-depth discussions and great learning and the first round can take up to an hour. During this time, the leader circulates, noting common issues that arise, sending students with interesting examples to the board, and otherwise facilitating a sometimes raucous discussion.

In the peer review, students must grapple with ideas in a classmate's homework that conflict with their own and figure out where errors in understanding the material or process have occurred. This grappling gives SSG students the opportunity to make, recognize, and correct their errors before they take an exam. The reviews are returned to the originator, who has a chance to decide whether to make any changes to the original assignment. The SSG leader collects the edited assignments and peer reviews and uses them in evaluating student performance.

The leaders provide feedback to students on their work and participation in the SSG sessions and use this feedback to assign SSG-session grades based on a scale of O (outstanding), S (satisfactory), and U (unsatisfactory). The course grade for an SSG student is determined in the same manner as it is for a nonSSG student (the exam scores). To receive the course grade with an honors designation, students need to receive an S or O grade in their

SSG section. A U in SSG results in the student receiving the honors designation, but the course grade is reduced.

SSG Leaders in Chemistry 215 ("Structure and Reactivity II")

During the second term of "Structure and Reactivity," students have two SSG options. First, they may choose to enroll in the 800-student mainstream course with an SSG option for honors credit. The SSG sessions are similar to those of the first semester with more challenging material and activities appropriate to the higher level course. A second option is taking a separate research-oriented section of the course with about 85 students; SSG sessions are required of all participants who take this option.

In the research-oriented option, there are two layers of SSG assignments. For the first layer, SSG leaders help design and implement a series of tasks that are comparable to those in the SSG sections for the larger course. For the second layer, SSG leaders help students create and carry out projects involving various technological environments. For one of these projects, for example, students constructed a resource on advanced chemical transformations that was incorporated into the course web site. Reading journal articles, understanding the chemical transformations described in them, and then creating animated reaction mechanisms and interactive assignments for their classmates causes the students to think like teachers. The technology project they create is fully owned by the students and they must seek out each other's expertise to understand the material and complete the project.

The SSG leaders in the research-oriented section do a great deal of work that would be impossible for one faculty member to do, including creating lessons on HTML authoring, locating appropriate software, and managing the logistically demanding task of coordinating the efforts of 85 individuals working on a single web site project.

Copies of the complete SSG curricula are available at the CSIE (Chemical Sciences at the Interface of Education) web site (The University of Michigan, 1999) along with representative examples of student work.

Outcomes

Forms of Assessment

We have collected six forms of assessment data on the SSG program: 1) exam performance for SSG honors students relative to nonSSG honors students and relative to honors students prior to introducing SSG, 2) numerical and narrative survey information from students at the end of their SSG experience, 3) reflections by SSG leaders, 4) performance-based assessments on a counterintuitive task the term after an SSG experience, 5) student reflections on SSG work at least one year following their experience but before they graduate, and 6) annotated student materials (a course portfolio) assembled by SSG leaders.

Exam Performance

We have demonstrated a link between participating in SSGs and better grades (Table 20.2). The average performance of honors college students after the introduction of SSGs *(Hpost)* is higher than the average of those before the introduction of SSGs *(Hpre)*, and the average performance of honors students who enrolled in SSGs (*HSSG*) is higher than honors students who did not enroll in SSGs (*HnSSG*). We analyzed the results and con-

Table 20.2 Comparative Exam Performance for Honors and SSG students, 1990–1998

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Hpre	4.0	8.2	7.0	5.2	*(6.10)*	*(6.10)*	*(6.10)*	*(6.10)*	*(6.10)*
Hpost					9.40	7.00	11.00	10.30	11.50
HSSG					10.80	8.33	13.00	15.70	15.10
HnSSG					0.14	2.52	6.61	2.57	3.37
nHSSG						11.90	14.10	10.40	15.92

H(Pre): The 1990–1993 difference scores represent actual differences, and the value of 6.1 between 1994–1998 is a calculated average from the 1990–1993 difference scores. It is used to show the expected difference score if SSGs had not been added to the course.

H(post): Difference scores after adding SSGs to the course. *H(post)* includes both those who participated in SSG (*HSSG)* and those who did not (*HnSSG)*.

HSSG (Honors SSG): Difference scores for honors students who elected SSGs (70-80%).

HnSSG (*Honors no SSG):* Difference scores for honors students who did not elect SSGs (20-30%).

nHSSG (*nonhonors SSG):* Difference scores for 25-60 nonhonors students who elected SSGs for honors credit each year.

cluded that the difference in performance between *HSSG* (7.0%–11.5%) and *H(pre)* (4.0%–8.2%, 6.1% average) can be correlated with participating in SSGs rather than that the academically better honors college students were self-selecting into the SSG sections. In practical terms, this difference in performance corresponds to one-third to two-thirds of a letter grade (i.e., B+ or A- instead of B). The procedures we used for that analysis are too detailed for this paper, but are available from the authors.

Numbers in the table are called difference scores, and represent the difference between the average course grade (percentage) for honors students and nonhonors students (e.g., 4.0 in 1990 is the difference between the 65.01% average of 571 nonhonors students and the 69.06% average of 95 honors students).

Numerical and Narrative Survey Information from SSG Students

We have collected student feedback from each SSG class. The average reply in Chemistry 210 and 215 has become more positive since the first time SSGs were offered. Chemistry 210 students report a high level of satisfaction with SSGs and their SSG leaders, and they are typically neutral on whether they would like to be leaders themselves. While these students support their SSG leaders comparably to those in the research-oriented section, their overall satisfaction with SSGs is not as high. This latter observation is aligned with other information we have about mainstream Chemistry 215, namely, that it is commonly taught in a "fact-heavy" way with less of the conceptual overview that SSGs are designed to support. In Table 20.3, we have listed representative responses from student surveys of Chemistry 210.

These numerical results are coupled with written statements that the students provide. Since 1994, 75%–85% of the written comments in a given year have supported SSG work, 10%–15% of the comments were neutral, and 5%–10% were negative or contradictory. See Table 20.4 for examples of the comments.

Reflective Memos From SSG Leaders

We collect reflective memos from the leaders during their service to monitor their development as teachers. These two brief excerpts are representative samples.

> One could never expect a group of novice learners to precipitate a useful exchange on a topic to which they have just been introduced .... [so] we leaders strive to first deliver a necessary amount of information, assist in its integration, and then facilitate conversation on the topic .... not only to catalyze and focus conversation but also to provide a model of an experienced learner.

> The most important lesson I learned was that the 'teacher' is never just an instructor, but a student as well for the rest of their life. This became evident after going through the program first as a student and then as an instructor .... I believe that my students taught me as much as I taught them .... I hope that [if I teach] ... I won't forget that I will always be a student.

Table 20.3 Sample of Student Survey Responses from Chemistry 210

	F94/102	F97/130	F98/150
The Chemistry 210 SSG assignments, group work, and participation:			
1) I made a motivated effort to do my best on my written assignments.	4.11 (0.5)	4.41 (0.7)	4.39 (0.7)
5) The in-SSG group work enhanced my understanding of Chem 210 topics.	3.76 (0.7)	4.36 (0.8)	4.17 (0.9)
6) Overall, participating in the SSG sections was of high value to me.	3.34 (0.6)	4.44 (0.9)	4.02 (1.0)
7) If I knew in September what I know now about SSGs, I would still elect it.	3.77 (0.7)	4.58 (0.9)	4.15 (1.0)
My Chemistry 210 SSG section leader:			
9) Overall, my section leader did an excellent job as an instructor.	4.22 (0.6)	4.72 (0.6)	4.50 (0.7)
The future after Chemistry 210:			
15) I would like to be a 210 SSG leader when I am a junior or senior.	2.96 (1.1)	3.09 (1.3)	3.11 (1.4)
17) I intend to participate in Chemistry 215 SSGs next term.	3.72 (1.1)	4.31 (1.2)	3.94 (1.3)

Scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree
F94/102: fall 1994; average of 102 student replies with standard deviation in parenthesis
F97/130: fall1997; average of 130 student replies with standard deviation in parenthesis
F98/150: fall 1998; average of 150 student replies with standard deviation in parenthesis

Performance-Based Assessments on Counterintuitive Task

SSG students spend two hours per week in sessions that emphasize peer review and analysis of the process of understanding concepts and solving problems, as well as the development of self-assessment skills. One of our expectations is that SSG students will realize that answers to homework problems can be the beginning of meaningful discourse about chemistry, not the end. We performed a study using an interview-based, think-aloud format in order to discover whether SSG sessions had helped students develop advanced problem solving behaviors, including computational chemistry skills.

We created three groups of subjects: an expert group of faculty and graduate students, an experimental group of students from the SSG groups, and a control group of nonSSG groups matched by academic performance in the chemistry course. The subjects were presented with data and asked to make a prediction, with the nature of the data being such that the most likely prediction would be the opposite of experimental results. An interviewer recorded the responses of the subjects as they described their thought processes. Once subjects made a prediction and elaborated on it, they turned to the second page, where they confronted the actual—counterintuitive—results of the experiment. The subjects were instructed to reconcile the actual results with their predictions and suggest a test for their ideas.

The expert group demonstrated the following attributes: 1) restating the problem, 2) taking an inventory of the major factors, making an early prediction, and following up with an extensive, elaborative explanation, 3) adopting a cyclical process of examination of a model, rejection on the basis of a counter argument, and proposal of a new model, and 4) utilizing primary literature sources, new experiment designs, and computational chemistry methods. About 80% of students who had participated in peer review exercises in the SSG sessions shared the same problem solving behaviors with the experts, while only about 20% of nonSSG utilized these behaviors (Coppola, Daniels, & Lefurgy, 1996).

Reflective Student Responses to SSGs

In January 1999, we collected feedback from 78 of the 390 former SSG students who were at least one year out of the courses. Students received an electronic mail request to reply to three questions. The replies were collected and categorized.

The first question stated that research showed that participation in SSGs strongly correlated with improved performance on Chemistry 210 exams and asked their opinion of this. The vast majority of respondents (93%) reported that this correlation made sense to them. The reasons offered by these students are congruent with benefits from participating in group learning: 1) the content is anchored to the real world because work is based on authentic, primary literature, 2) providing explanations builds confidence, 3) the format provides chances to explore unknown material and lessens tendencies to oversimplify explanations or rules, 4) discussions are guided by mutual respect, not spoon-feeding, 5) the format encourages the asking of questions, and 6) the format provides opportunities for not-so-perfect explanations to develop into better ones.

The second question asked students to consider which aspects of participating in SSG sessions might have impacted their student life beyond their performance in Chemistry 210. All responses were favorable. They said that SSG sessions 1) permitted them to work with others

Table 20.4 Sample Comments on Student Surveys

Type of Comment	Sample Comments
Positive comments (75%-85%)	"It doesn't allow me to convince myself I know something, but forces me to demonstrate and teach that knowledge." "SSG made me feel much more confident about my chemistry understanding through extra practice and talking with other students." "At first, SSG seemed time consuming and confusing because of the new ideas and information, but very quickly it cleared up any confusion I had in Chem 210 overall and I became confident with my assignments and I started to see them as very interesting."
Neutral Comments (10%-15%)	"There's a lot of work." "It was not as hard as I thought it might be."
Negative or Contradictory Comments (5%-10%)	"I put in a whole lot of work and didn't reap that many benefits." "I think a lot of stuff was pointless and busy work, but a good portion helped us out in chemistry."

who have differing points of view, 2) provided a community of people willing to help, whether in class, in the residence hall, or by email, 3) created a smaller space in a large university, a place to call their own, 4) opened their eyes to the possibilities of teaching, and 5) that familiar faces from the SSG session made lab and lecture less intimidating.

The third question asked their opinion of an honors option that deviated from the traditional honors model of offering segregated sections and that used upper-level undergraduates as instructors. Once again, SSG students were unanimous in their support, saying that leaders have "the authority of recent experience" as chemistry students, understand students, are approachable and understanding, and create an environment where fear of doing an imperfect job is reduced.

Productivity

The Undergraduate Initiative, a discretionary fund administered by the College of Literature, Science and the Arts (LS&A) provided the initial investment for the SSG experiment from 1994 to 1997. The major cost for running the SSG program is stipends for the SSG leaders, who are paid through the honors office in the College of LS&A. In 1998, the college included SSG as a permanent budget item for the honors office.

SSG leaders are paid at the rate of $1,080 per term, 12 weeks x six hours per week (four hours for preparation and grading, and two contact hours) x $15/hour. In the Fall 1998–1999 term, 12 SSGs served a total of 175 students at a total cost of $12,960. The honors office and the Department of Chemistry supplement this budget by covering the cost for the weekly staff meeting, which is held over lunch. Food expenditure for 1998–1999 was $1,750 (for 13 people for 13 weeks). From a practical standpoint, the cost for the leaders' stipends and meals ($14,710 in fall 1998–1999) is significantly lower than a faculty member's separate course assignment in each of two terms (about $30,000 per term), and six graduate student instructors teaching two SSG sections each (at $12,500 per year per graduate student for a total of $75,000). Based on 175 students in 12 SSGs during the first-term course, the cost for the SSG program is $84 per student in the SSG sections, while a separate course would be $600 per student. Although tuition would be collected for a separate section of the course, this figure does represent an add-on cost, the least cost-effective portion of which would be an increase in the department's teaching load.

Suggestions for Replication

Dealing with Initial Resistance

Although our campus has a tradition of using undergraduate students to help with teaching, using them as primary instructors for an honors option was controversial. How did we overcome this resistance? Initially, we argued for an experimental program by citing the benefits of student-centered classrooms and peer-led instruction. Once we began to gather experience, we found that using the assessment data on the program, as well as offering a few well-timed presentations by SSG leaders at the Honors Advisory Board meetings, readily dispelled the resistance.

Selecting Undergraduate Instructors for Demonstrated Potential

We have found that having the SSG leaders nominate the next generation of leaders from among their students is an excellent method of finding the best replacements. Leaders observe their students' nascent teaching skills and can provide highly informed recommendations about who would make a good SSG leader. Also, we ask potential leaders to write an essay describing their interests, abilities, and motivation for becoming SSG leaders. To date, a triangulation of information (leader impressions, faculty impressions, and an essay) has worked successfully for us.

Importance of Faculty-Leader Collaboration

Faculty and student leaders need to fully understand the collaborative responsibility that this system requires. SSG leaders are part of a teaching and learning team, and leadership for the program is shared. Faculty must be willing to develop student leadership and then delegate real responsibility to the leaders. Faculty must also remember their responsibility as mentors because SSG leaders are still students learning to teach and lead. SSG curriculum materials should also be developed collaboratively by faculty members experienced with curriculum design and students with insight into the learning process.

Not Using Traditional Textbook Problems

Each assignment strikes a balance between enough of an open-ended problem to promote creativity ("create and rank five molecules") and enough structure to keep the tasks similar enough for students to encounter the same concepts along the way ("within these specified criteria"). Congruent with the tenets of reciprocal teaching, SSG leaders reflect on their own understanding in order to design tasks that reveal the smaller steps in problem solving that novices need to consider explicitly. A copy of the most recent SSG curriculum materials is available at the CSIE web site (The University of Michigan, 1999).

Conclusion

Even more than an effective instructional method, the SSG program is a cornerstone to a broadened vision of scholarly development for future faculty (see the CSIE web site for a detailed discussion). Historically, curricular design has allowed students to demonstrate their potential for research (e.g., in a first-year chemistry laboratory) and be moved into positions of increasing independence and leadership (namely, undergraduate research). So, too, is the design of the SSG program, where the curricular tasks develop students' explanatory knowledge and allow them to demonstrate their potential for teaching. SSG leadership is the position of independence and leadership into which students with these skills can move. The first generation of SSG leaders who have gone to graduate school have carried a strong, positive imprinting experience that has affected their teaching as graduate student instructors and, we predict, their careers as future faculty members.

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