Exciting undergraduates towards organic chemistry – the study circle approach

Lakshmy Ravishankar, Savita Ladage and Gomathi Shridhar*

In recent years, students' enrollment for undergraduate courses in science is a cause for concern. Often students enrolled for conventional undergraduate courses are perceived as unsuccessful and thus a large fraction is hesitant to appear for any standard competitive examinations available within the country. Students who major with chemistry often want to continue with organic chemistry, but find it a difficult and volatile subject. With the examination system laying more emphasis on rote learning, students often study this subject by memorizing the facts with little or no understanding. To address these issues, an activity of a study circle was initiated almost two decades ago in one of the local colleges in Mumbai and the present article reviews this effort and its outcome.

Keywords: Organic chemistry, problem solving, undergraduate teaching.

In recent years, the enrollment of students for undergraduate courses in science is a cause for concern. It has been observed that there is a steady decrease in the number of students taking admission for undergraduate courses, particularly at University of Mumbai. Further, those who take admissions prefer to enroll for non conventional B Sc programmes, that is, B Sc with specialization in information technology and biotechnology over the conventional courses. Another observation is that those who opt for conventional courses often have scored less in their class XII examination, average scores being between 50% and 60%. Most of these students are perceived as unsuccessful by their peers and society, and hence they end up having low self-esteem. The fear of failure is embedded in their minds, as a result of which they hesitate to appear for competitive examinations for admission to M Sc and integrated Ph D programmes of reputed institutes. Students who opt to major in chemistry do so as they believe it gives them an opportunity to work in chemical industries. Among the different branches of chemistry, the most sought after specializations at the Master's level are organic and analytical chemistry, as students directly connect these areas to chemical industries.

Overload of reactions, reagents, functional group transformations, mechanisms and stereochemistry makes organic chemistry difficult for an average student to cope with. Further, the current examination pattern lays more emphasis on rote learning rather than understanding the concepts. Despite the efforts put to study the subject, the output is not commensurate with the efforts, which demoralizes students and kills their interest.

Most of the organic chemistry will not be perceived as a load if one understands a few basic principles and the many extensions and applications of these principles. If a student grasps these major concepts and develops logical reasoning in applying them, relatively little memorization is required. For example, while the number of named reactions may be running into hundreds, understanding the mechanism would require being thorough with few basic concepts like that of electrophile, nucleophile, acid–base concept, classification of reactions, use of curly arrows, etc. all of which may add up to only about 20 fundamental mechanistic steps that combine into the longer and more complicated mechanism.

Study circle

To address these different issues, the idea of a study circle was initiated in one of the local colleges of Mumbai almost two decades ago. The main objective of the study circle was to build confidence among students, motivate them towards academic careers and help them overcome their fear of organic chemistry.

Problem-solving is an activity that actively engages the learner. It helps students to not only judge whether they have understood the subject, but also tests their ability to apply the fundamental concepts learnt and to arrive at solutions to different questions. Unfortunately the curriculum of many Indian universities does not provide much scope for extensive problem-solving.

Lakshmy Ravishankar is in the Department of Chemistry, V.G. Vaze College of Arts, Science and Commerce, Mithagar Road, Mulund (East), Mumbai 400 081, India; Savita Ladage is in the Homi Bhabha Centre for Science Education, Tata Institute of Fundamental Research, V.N. Purav Marg, Mumbai 400 088, India; Gomathi Shridhar is in the Department of Chemistry, V.K. Krishna Menon College of Science and Commerce, Bhandup, Mumbai 400 042, India.
*For correspondence. (e-mail: lakshravi@yahoo.com)

The study-circle approach was chosen almost intuitively. Participation in the study circle was voluntary, the only requirement being that the students should be willing to devote some time in a week to problem-solving activity. The group, comprising about 6–12 students from the final year B Sc programme would meet once a week after regular lectures for about 2 h.

Pedagogy

The pedagogy employed in the study circle involved a brief overview of the fundamentals of a particular topic followed by problem-solving as it encourages the students to think, discuss and debate. Further, the small group size of the study circle facilitated one-to-one interactions within the group.

Typically, the first session of the study circle is generally devoted to revision of the basic concepts which students should know as chemistry majors. While revising the concepts, the emphasis is not on teaching as it happens in regular classes. Short and multiple choice questions related to a particular topic for example, acid–base concepts, factors affecting reactivity, are given to students and they are encouraged to discuss the same. In the initial stages, when students are unsuccessful in solving the given problems, standard reference books are made available for reading. These efforts help in enhancing the participation of students and slowly the discussion becomes student-centred rather than teacher-centred.

The problems used in the study circle were collected from different sources such as standard reference books and internet resources, past papers of various competitive examinations in addition to problems formulated by the instructor. These could be either take-home problems as assignments or class-work problems. In the case of the former, students would solve the problems as a home assignment and discussion on the same would be done the following week. In such cases, it was observed that students got time to engage with the problems and thus after few classes, they became vocal, active and were willing to discuss their solution with others. In fact, students were asked to use the blackboard for presentation of their solutions.

While most of the topics discussed in the study circle are part of the undergraduate syllabus, advanced problems were also chosen as they often demand understanding of several concepts and their interconnections. Such problems generated opportunities where students had to recall appropriate concepts and relate them. Such involvement with higher-order cognitive processes is important and useful in broadening the understanding of the subject.

Qualitative observations

The change in the approach of the students towards the subject was generally visible after participation in four to five sessions of the study circle. Initially, they were often confused regarding where and how to begin solving the given problem. More often than not, they would lose their confidence and talk of dropping out, when they were not able to solve the problems. Motivating and encouraging them with minimal guidance at this juncture, helped them to overcome their mental barriers and bring about a change in their attitude towards problem-solving. For example, while writing mechanisms, the concept of arrows and their significance was often lost and we would come across answers where they would show migration of a positive charge by means of arrows, or draw the arrow from the electrophile to the nucleophile instead of the other way around. A few sessions involving discussions increased the comfort level of the students and most of them were able to identify the electron-rich and deficient centres in a reaction. Once that was identified, writing mechanisms became much simpler. Similarly, mechanisms in acidic medium and alkaline medium were also confusing to the students, with many writing positively charged intermediates in an alkaline medium and negatively charged intermediates in an acidic medium. These concepts although simple, are vital and often overlooked by the students.

The enthusiasm of the participants of the study circle was such that sometimes they would develop questions pertaining to the regular lectures and try to solve it on their own and discuss it with their peers. Often several solutions would be possible for a particular synthesis and the group would discuss the merits and demerits of each of them. Another outcome, observed was that students would come out with questions related to their experiments in the laboratory. For example, when any synthesis was carried out, participants of the study circle would often attempt the mechanism, spectral data, etc. of the compound, even before the instructor asked them.

This entire process helped develop confidence amongst the students and they also made attempts to understand basic concepts and their applications to other branches of chemistry, viz. physical, inorganic and analytical chemistry. Participation in the study circle improved the reading habits of the students, which is a substantial gain as it improved their knowledge. It was observed that many of the participants took part in intercollegiate academic competitions like quiz, paper presentations, etc.

Outcome

One of the most significant outcomes of the study circle was the development of the departmental library managed by the students. Over the years, several reference books from all branches of chemistry have been added to the library, which now boasts of a good collection of books which are regularly used during the study-circle sessions.

This has inculcated the habit of referring to books other than the prescribed textbooks of local publishers.

Recently, a survey was conducted with past participants of the study circle to understand the long-lasting effects of this activity. A questionnaire was given to students who had attended the study circle over the years. Thirty-four students (out of 50) responded to the questionnaire. Most participants categorically stated that the study circle made them confident with respect to chemistry and improved their conceptual understanding, particularly in organic chemistry. In fact, these participants emphasized that such opportunities should be available from the first year of the B Sc course and in different areas of chemistry. Of the 34 respondents, 33 have taken up a career in chemistry and most of them are pursuing academic careers (26 students) in India and abroad, whereas the rest (7 students) have joined chemical industries. These facts indicate that the study circle did play a significant role in motivating students to take academic careers in chemistry.

Often these past participants willingly visit the college and interact with their juniors and share their experiences and their current areas of work. These interactions further boost the morale of the junior students and probably, this is the reason why the study circle has been running successfully year after year.

The benefits of the study circle have trickled to the sophomores as well and now this activity is extended to the second year B Sc students. With positive outcomes, in recent years, several problem-solving workshops have been organized for students from different colleges in Mumbai. The response to these workshops has been encouraging and the feedback received strongly suggests that students are keen to have such problem-solving sessions as a part of classroom teaching.

In colleges, tutorials are not an integral part of the regular teaching and thus, in the classroom, teaching occurs in transmission mode. We strongly feel that the problem-solving sessions in the form of tutorials must be made an integral part of regular teaching in the classrooms. Even in large classrooms, students can be divided into groups and problem-solving sessions can be conducted effectively. We may have to sacrifice some content for integrating the problem-solving sessions as part of regular teaching. The emphasis during these classes should be on discussions leading to the answer and not the answer alone. Thus, students go through the entire process of solving problems and are able to analyse and reflect upon various problems. If the teaching of chemistry in classrooms is not preparing students for conceptual understanding, then they are bound to suffer even though they may be successful in the conventional examinations. Our experience tells us that such sessions help develop students' interest in organic chemistry and also changes their perception about the subject.

Another effective way is to expose teachers to the problem-solving approach. In university systems, refresher courses are conducted on a regular basis. These courses often have content lectures which are important. Being in the teaching profession, we feel such courses should have pedagogical inputs. Different approaches for effective teaching are equally important and as practitioners, teachers must be exposed to new methodologies that can be implemented in classrooms. Exposure to problem-solving in workshop-mode is useful for teachers as they themselves will debate this approach. Unless teachers are exposed to how to initiate problem-solving as part of the curriculum, they will not be willing to adopt it. We have delivered a few lectures in some of the refresher courses, but there is still a long way to go. Exposure to pedagogical aspects (areas in the realm of chemistry education) is not yet considered as an equally important aspect, at least for refresher courses.

At the first International Conference on Education in Chemistry (ICEC 2010) held at the Homi Bhabha Centre for Science Education, Mumbai in November 2010, experts were invited who exposed undergraduate level chemistry teachers to different problem-solving-based approaches[1].

What was initiated as a small step to address certain issues that exist in regular undergraduate teaching has turned out to be a meaningful activity for those students who had low self-esteem and were not considered to be bright at their entry point. The satisfaction of seeing so-called average students excelling in academics and taking up careers in chemistry provides us an impetus to continue conducting this activity and expanding it further.

1. Ladage, S. and Samant, S. D. (eds), *Chemical Education*, Narosa Publishing House, New Delhi, 2012, ISBN 978-81-8487-197-5.

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