

# Art of Writing Flowchart in Organic Chemistry Practicals Induces Logical Thinking in Chemistry Students

Toreshettahally R Swaroop<sup>1\*</sup>, Chalya M Shivaprasad<sup>2\*</sup>, Kanchugarakoppal S Rangappa<sup>3\*</sup>

<sup>1</sup>Department of Studies in Organic Chemistry, University of Mysore, Manasagangotri, Mysuru-570 006, Karnataka, India

<sup>2</sup>Department of Chemistry, Government First Grade College for Women, Vijaya nagara, Mysuru – 570 032, Karnataka, India

<sup>3</sup>Institution of Excellence, University of Mysore, Manasagangotri, Mysuru-570 006, Karnataka, India

## \*Corresponding Authors

Toreshettahally R Swaroop, Department of Studies in Organic Chemistry, University of Mysore, Manasagangotri, Mysuru-570 006, Karnataka, India. Chalya M Shivaprasad, Department of Chemistry, Government First Grade College for Women, Vijaya nagara, Mysuru-570 032, Karnataka, India. Kanchugarakoppal S Rangappa, Institution of Excellence, University of Mysore, Manasagangotri, Mysuru-570 006, Karnataka, India.

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## Abstract

In this article we present an art of writing flowcharts in organic chemistry preparation practicals. We divided students into two groups. One group of students was trained to write procedural flowchart and the other group of students was educated to write chemical flowchart for the preparation of *p*-nitroacetanilide from acetanilide and preparation of hippuric acid from glycine. The procedural flowchart simply represents the steps involved in an organic preparation. While, chemical flowchart describes chemical species involved in each step of preparation. We found that students educated to write chemical flowchart have gained superior knowledge in chemistry over the students who were trained to write procedural flowchart.

**Keywords:** Flowchart, Procedural, Chemical, Practicals, Preparation, Thinking

## Introduction

Flowcharts were first introduced in 1921 in the American society of mechanical engineers. They were very popular in 1950s in the area of computer science. A flowchart is an illustrative diagram which present the steps involved in any process from beginning to end with an aid of boxes with flow arrows. They are often called as process maps. Besides, they represent textual relationships, which are connected by time. Students explain a sequence of events, phases, stages and actions which lead to an outcome. In many instances, they are used in machine learning and deep learning in physics, to describe an experiment in chemistry and to illustrate life cycle of organisms in biology.

Explanation on the use of flowchart is complex. However, it can be constructed based on purpose. Besides, subject expertise is needed in constructing flowchart. Flowcharts may be classified as procedural, implementation and evaluation [1]. At first, in procedural flowchart, we represent simple and essential steps involved in a protocol. Secondly, in implementation flowcharts, essential steps and decisions required to implement a protocol are mentioned. Thirdly, implementation flow charts are used to represent efficiency of a particular involvement or teaching plan. It is also called as decision making flow chart [1].

Flow charts help to identify essential steps involved and represent the complete pictorial diagram of a process. Each step in flow chart describes what is happening in that step. Besides, each step is arranged in chronological order. Our literature revealed the lack of education research articles on flowcharts and their applications in chemical education.

In the area of chemistry, we use flowcharts to describe an experiment, particularly in organic chemistry practicals at the University of Mysore. Procedural flow charts are useful in describing an experiment in practical sessions of organic chemistry.

We are working full-time in chemistry and medical chemistry [2-10]. As a part-time work on chemical education, we have recently published an article on inquiry-based teaching method, which induces cognitive thinking in post graduate students [11]. In continuation of this work, we herein disclose the importance of art of writing flowcharts in organic chemistry practicals, which enhances logical thinking among student community.

## Experimental

We designed experiments on art of writing flowcharts in organic chemistry practicals in two batches of students with a total strength of forty. First twenty members were trained by the first author and second batch of twenty students were taught by teacher X. Post-experimental data were collected by the first author. The data were collected by practical record books of organic chemistry students and are analyzed in results and discussion part and concluded at the end of manuscript. In our method of writing flowchart, we trained our students in such a way that what is happening in an organic chemistry experiment.

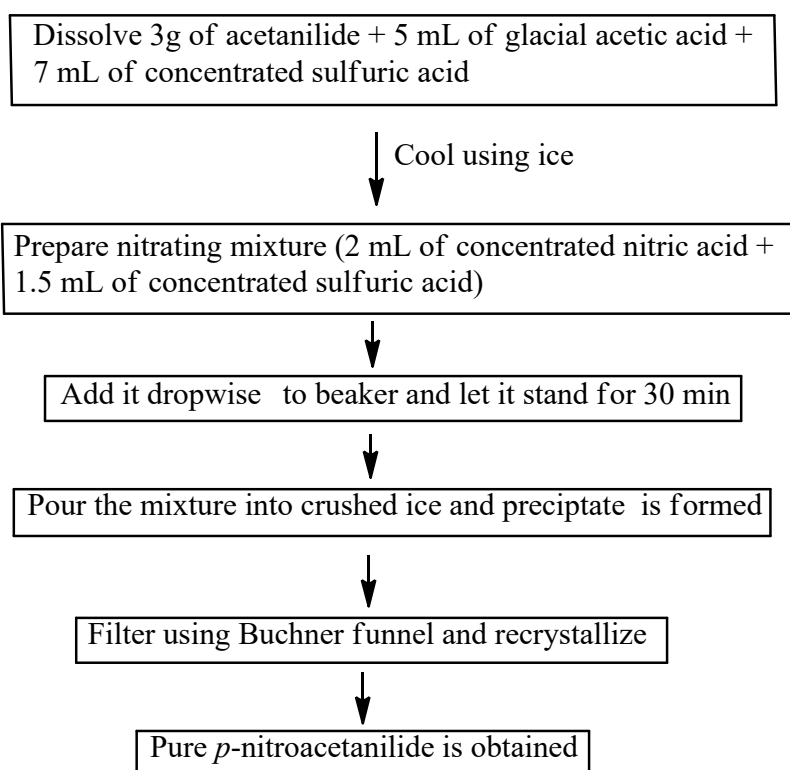
## Results and Discussion

We selected an experiment in organic chemistry practical and trained two batches of students. The batch-I was trained by the first author and the batch-II was taught by teacher X. We opted 'preparation of *p*-nitroacetanilide from acetanilide by nitration' as

a model experiment. The general procedure for the preparation of *p*-nitroacetanilide from acetanilide is given below.

*Dissolve 3 g of acetanilide in 5 mL of glacial acetic acid and 7 mL of concentrated sulfuric acid. Keep the warmed clear reaction solution in freezing mixture. Add slowly the cold solution of nitrating mixture (2 mL of concentrated nitric acid and 1.5 mL of concentrated sulfuric acid) into the reaction mixture by maintaining the temperature below 10°C. After addition, keep the reaction mixture at room temperature for half an hour. Pour the reaction mixture into a beaker containing 150 g crushed ice. Filter the precipitate and dry. Recrystallize a small portion of product from ethanol.*

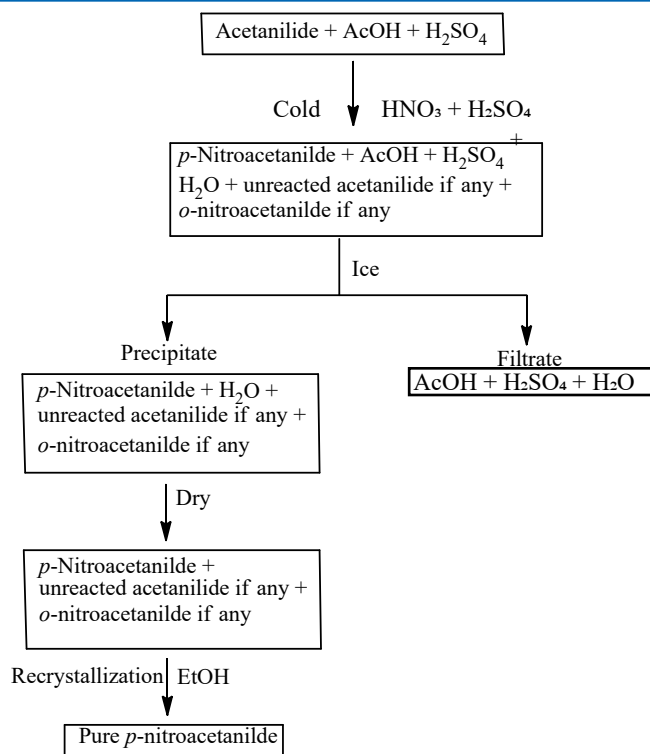
The batch-II students trained by teacher X wrote procedural flowchart like below (Figure 1).



**Figure 1:** Procedural Flowchart Written by Batch-II Students Taught by Teacher X

On the other hand, the first author educated students of batch-I to write flowchart in the other way. We taught students to write chemicals, reagents and compounds involved in each step. We would

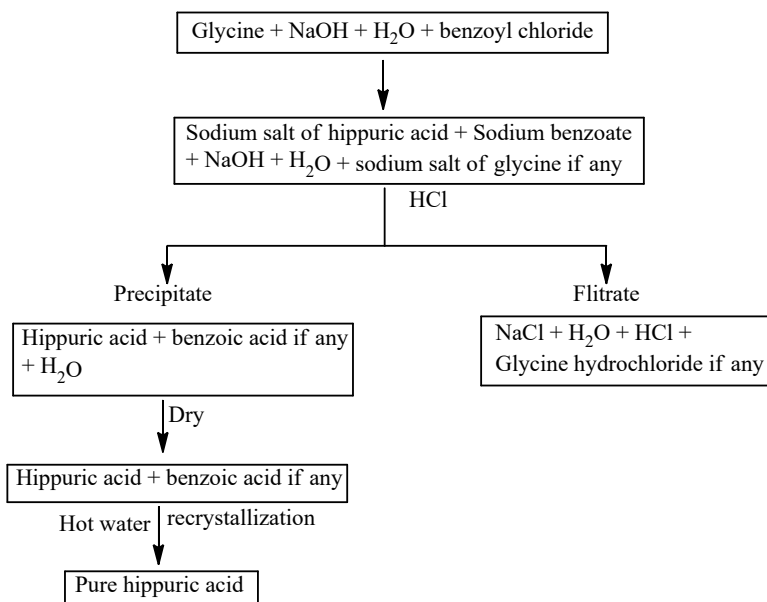
like to call the flowchart which represents chemical species involved in each step as 'chemical flowchart'. The advised flowchart to batch-I students is given below (Figure 2).



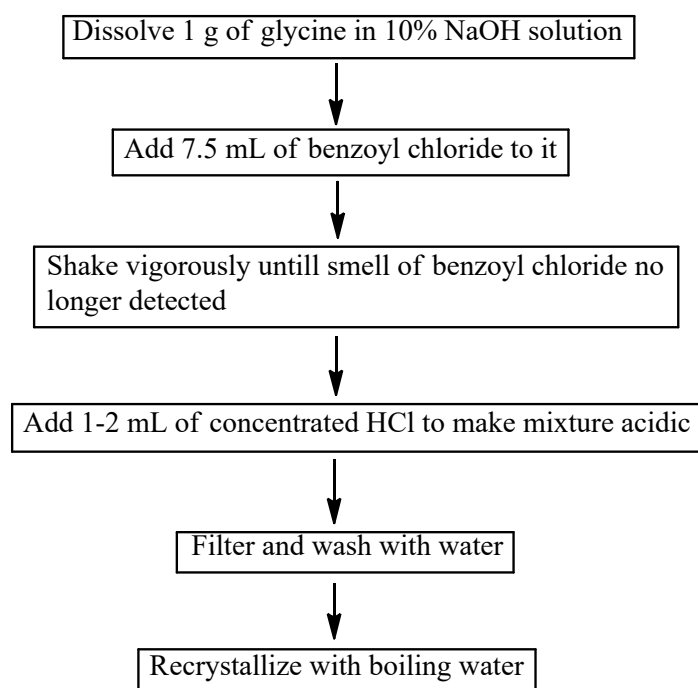
**Figure 2:** Chemical Flowchart Advised to Batch-I Students by the First Author

Our batch students were inspired by this kind of writing flowchart. On the other day, we planned another experiment in organic chemistry practicals. We instructed batch-I students to do preparation of hippuric acid from glycine and to write chemical flowchart. Our students applied their knowledge to write chemical flowchart, which is given in Figure 3. The batch-II students, as usual wrote procedural flowchart (Figure 4). The procedure for the preparation of hippuric acid from glycine is given below.

*Dissolve 1 g of glycine in 20 mL of 10% sodium hydroxide solution and add 7.5 mL of benzoyl chloride to it. Plug the mouth of the flask with cotton and shake vigorously until the smell of benzoyl chloride is no longer detected. Then add 1-2 mL of concentrated hydrochloric acid to make the mixture acidic. Filter the product using Buchner funnel, wash with water, dry and recrystallize a portion of product from boiling water.*



**Figure 3:** Chemical Flowchart Written by Batch-I Students



**Figure 4:** Procedural Flowchart Written by Batch-II Students

Thus, all students come under batch-I wrote chemical flowcharts to all organic chemistry laboratory preparations, which took them to a great level of logical thinking.

### Conclusion

In conclusion, we trained students of organic chemistry to write chemical flowchart to all preparations in organic chemistry laboratory. We define chemical flowchart as the one which gives complete chemical information in an organic preparation at each step. Training students to write chemical flowchart rather than procedural flowchart enhanced the thinking capability. Thus, students can understand what is happening in each step of organic preparation. Also, we compared the output on students who were involved in these experiments. The students who were educated to write chemical flowchart were successful in passing prestigious national level examinations for research fellowships. Besides, they were able to get positions in pharmaceutical companies in campus interviews. Thus, we recommend all teachers to introduce the concept of writing chemical flowchart in organic chemistry laboratory preparations.

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