Presentation

A cognitive approach to team-based learning in basic chemistry

John Georg Seland

Department of Chemistry, University of Bergen, Norway

Abstract: Team-based learning (TBL) was implemented and adapted to a course in basic chemistry. As a part of the adaptation, information processing, a concept from cognitive science was implemented in additional lectures (called information processing lectures), which would normally not be included as a part of the TBL structure. The data show that the students on the lower end of the grading scale benefits from the TBL activities, with a lesser impact on the students on the higher end of the scale. Results from student surveys and the teacher's in-class observations indicate that the students find TBL teaching beneficial, and that the information processing lectures helps to clarify the more challenging concepts in the course and to avoid misconceptions that can be carried over in higher level courses.

Keywords: basic chemistry, flipped classroom, cognitive science, information processing, active learning, team-based learning.

1 Introduction

1.1 Information processing in chemistry

Basic chemistry can be challenging for students without prior exposure to the subject. Misunderstanding key concepts is common, making it crucial to adopt effective teaching strategies. Johnstone (Johnstone, 2010) have developed a systematic framework for chemistry education based on an 'information processing' model from cognitive science (Atkinson & Shiffrin, 1968). This model includes three components: the perception filter (attention), working memory, and long-term memory. Since the working memory has limited capacity, it can be expanded using 'chunking' (Johnstone, 2010) , where smaller units are grouped to aid comprehension. Johnstone further introduced a working model of the three components of the 'nature of chemistry', described as macro (observations), submicro (atoms, molecules, ions), and representations (symbols, formulas, equations) - visualized as a triangle (Johnstone, 2010), which is presented in Figure 1. Effective teaching in chemistry classes requires careful movement between these components to avoid overloading the working memory, and to avoid moving too quickly to the middle.

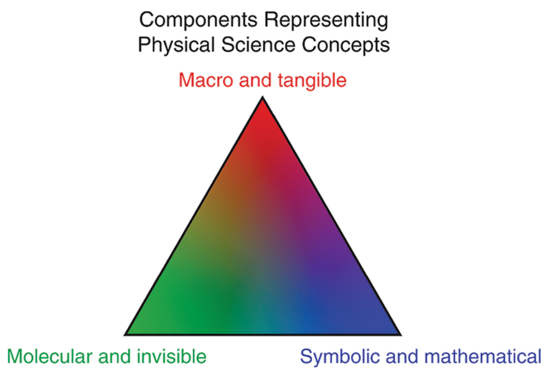

Figure 1. Johnstone's triangle with the three components of the 'nature of chemistry' (Johnstone, 2010).

1.2 Team-based learning in chemistry

Multiple studies have shown that active learning increases student performance in science, technology, engineering, and mathematics (STEM) diciplines (Freeman et al. 2014). Recently, studies on the impact of active learning in university courses in chemistry have been performed (Eichler 2022, Kovac 2022, Lehki & Varao-Sousa 2023). Team-based learning (Sibley et al. 2014) is a type of active learning that is known to enhance student engagement. In TBL students are stimulated and encouraged to participate in activities by introducing smaller teams in a large class (Sibley et al. 2014). The well-structured and systematic approach to student activities in TBL ensure that students are held accountable for their own learning. However, in its original form it involves a totally flipped classroom with no organized lecturing, which can be a challenge for students that are novices in chemistry.

1.3 Combining information processing with team-based learning

When introducing TBL in a basic chemistry class, one should not forget the limited capacity of the working memory (Johnstone, 2010). The students can very quickly get the feeling of being overloaded with abstract chemical concepts and find it difficult to connect these concepts (submicro) to macroscopic observations using the language of chemistry (symbols, formulas, equations). However, TBL is very suitable for identifying these challenges, since the activities allow the teacher to get a good overview of potential misconceptions and concepts that the students find challenging, but time should be allocated to lectures where the challenges can be addressed. This paper describes how TBL has been combined with information processing in a course in basic chemistry, where student activities are combined with specially designed lectures (called information processing lectures).

2 Implementing team-based learning in chemistry

2.1 The team-based learning part

TBL was implemented in a basic chemistry course at University of Bergen, attended mainly by students in biology and earth science, and with a total student number of approximately 200 in total. A lab course with 4 exercises with written lab reports is a mandatory part of the course but will not be included as a part of this study. Traditionally a course like this would include 4 x 45 minutes of lectures, together with colloquiums (passive problem solving) lead by student assistants. To facilitate TBL the students were divided into 30 teams, with 6-7 students in each. The students cannot choose their own team and are also member of the same team throughout the course. For pre-class activities the students had access to video lectures and recommended reading in the textbook. The curriculum was divided into 8 modules, each with a duration of two weeks. Each module starts with an in-class *introduction-lecture* (2 x 45 min, not mandatory), where the lecturer introduces the main topics, with a special focus on the right approach to information processing (see below). This is followed by mandatory (5 out of 8) Readiness Assurance tests (RATs), with an individual part (iRAT) and a team part (tRAT), according to the recommended TBL structure (Sibley et al. 2014). The scores on the RATs, the 5 best scores, weighted 40/60 with respect to iRAT/tRAT, contribute to 25 % of the total grade in the course. A written exam accounts for the remaining 75 %. The students are then invited to attend an in-class *review-lecture* (2 x 45 min, not mandatory) where the lecturer clarifies the more challenging concepts and misconceptions, selected from the data obtained in the RATs and from observations and discussions with students during these tests. The module concludes with Application Activities (AAs) where the students work in teams to solve problems that focuses on a deeper understanding of the topic.

2.2 The lecture part

In the in-class introduction lecture, the new chemical concepts are carefully presented. The lecturer starts with presenting a macroscopic observation, explain what is happening on the submicro level (atoms, molecules, ions) and which representations (symbols, formulas, equations) are used to express these observations. As an example, consider a combustion (macroscopic observation), where a hydrocarbon reacts with oxygen to form water and carbon dioxide. The structures of the substances involved are described (atoms with chemical bonds to form molecules and on the submicro level). The expression for the reaction with reactants and products can be written (equation as a representation). One can then introduce other examples and gradually move toward the center of Johnstone's triangle (Figure 1) where all the different components are present, and one can also move more quickly between components. When clarifying the challenging concepts and misconceptions in the review-lecture, a similar approach is used, but now the lecturer can use the data and in-class observations from the RATs to optimize the paths taken in Johnstone's triangle.

2.3 Data collected

All the scores form the RATS performed in 2023 and 2024 were collected, together with the scores from the written exam. In addition, student surveys were performed at the end of the course in 2023 and 2024. All data were collected anonymously.

3 Results and Discussion

3.1 Data from the readiness assurance tests

As examplified in Figure 2, where data from two RATs executed in 2023 are presented, the students obtain a higher score on the tRAT compared to the iRAT. Data from the other RATs, executed in 2023 and 2024, show the same general trend. This is expected in a TBL setting where the students are given the opportunity to discuss within the team during the tRAT (Sibley et al. 2014).

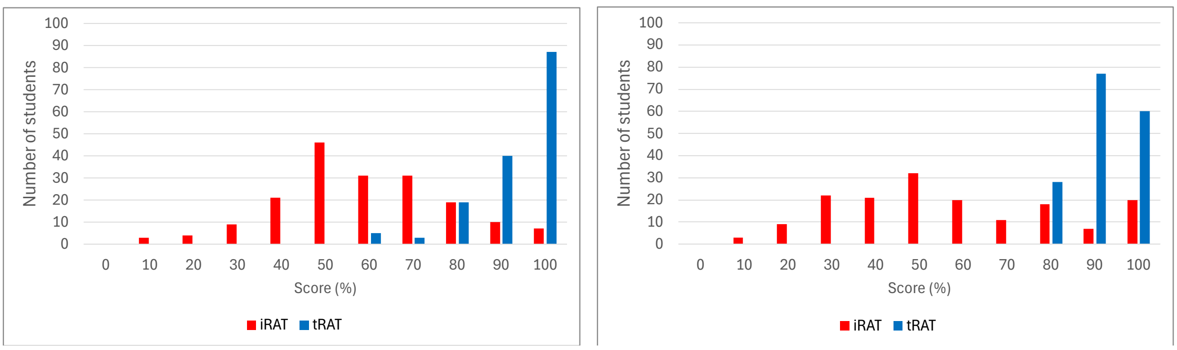

Figure 2. Comparison of the obtained scores on two selected iRAT and tRAT activities.

Another interesting approach for analysing the RATs' impact is to compare the score on the RATs with the total score for each student, sorted according to the student's final grade in the course, as presented in Figure 3. All the students had a score on the RATs in the range 70 – 90 %. The students with final grades A – B (higher than 75 %) have similar and high values on the score for the RATs and final score, while students with lower grades have a larger gap between these two scores. Notably, the score on RATs is correlated with the final grade, i. e. the students with the lowest final grade also obtained a lower score on the RATs. This trend is particularly clear in the data from 2024.

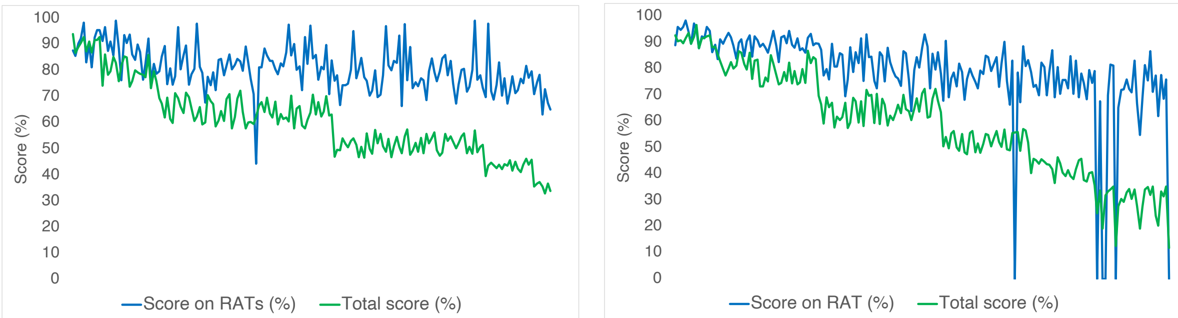

Figure 3. Comparisons of the total score (RAT and final exam) and the score on the RATs for each student, sorted according to the final grade obtained in the course in 2023 (left) and 2024 (right). Total score and final grade: A: 100 - 90 %, B: 89 – 75 %, C: 74 – 60 %, D: 59 – 50 %, E: 49 – 40 %, F: less than 40 %.

The scores from the RATs have a significant impact on the final grades obtained in the course, particularly for the students with a low score on the written exam, where some of them would have failed the course if the scores from the RATs were not included.

These findings are similar to data obtained in other studies (Freeman et al. 2014, Lehki & Varao-Sousa 2023).

3.2 The teacher's observations and feedback from the students

Student surveys performed in 2023 and 2024 reveal that a majority of the students (70 %) prefer TBL teaching compared to traditional lectures, and that they experience high learning outcomes from TBL classes (RATs and AAs). This is contrary to the more common findings is such studies, where most students prefer, and also experience that they learn more, from traditional lecturing (Sibley et al. 2014, Freeman et al. 2014). The teacher finds it very beneficial to use the TBL classes to identify the concepts that the students find the most challenging, and to clarify these concepts and potential misconceptions in the information processing lectures.

4 Conclusion

This paper has presented data and observations from an implementation of team-based learning combined with specially designed information processing lectures in a course in basic chemistry. The data shows that more students pass the course when the scores from RATs are included in the grading. The students with a high score on the written exam in not strongly influenced by the results obtained in the RATs. One can therefore conclude that TBL activities is beneficial to the students that are located on the lower end of the grading scale. Results from student surveys and the teacher's in-class observations indicate that the students find TBL teaching beneficial, and that the information processing lectures helps to clarify the more challenging concepts in the course and to avoid misconceptions that can be carried over in higher level courses.

References

Johnstone, A. J. (2010). You Can't Get There from Here. Journal of Chemical Education, 87(1):22–29.

Atkinson, R. C. and Shiffrin, R. M. (1968). Human Memory: A Proposed System and its Control Processes. Psychology of Learning and Motivation, 2:89–195.

Freeman, S. Eddy, S. L. , McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. and Wenderoth M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, 111(23):8410–8415.

Lekhi, P. and Varao-Sousa, T. (2023). Implementing team-based learning in a large environmental chemistry course and its impact on student learning and perceptions. *Chemistry Education Research and Practice*, 25(1):193–211.

Eichler, J. F. (2022). Future of the Flipped Classroom in Chemistry Education: Recognizing the Value of Independent Preclass Learning and Promoting Deeper Understanding of Chemical Ways of Thinking During In-Person Instruction. *Journal of Chemical Education*, 99(3):1503–1508.

Kovac, J. (2022). Student Active Learning Methods in General Chemistry. Journal of Chemical Education, 76(1):120.

Sibley, J. Ostafichuk, P. Roberson, B. Franchini, B. and Kubitz, K. A. (2014). Getting Started With Team-Based Learning. Stylus, Sterling, Virginia, 1 edition.