Metacognitive Strategies in the Preparation of Future Chemistry Teachers

Mária Ganajová, Pavol Jozef Šafárik University in Košice, Slovakia
Ivana Sotáková, Pavol Jozef Šafárik University in Košice, Slovakia
Mária Kožurková, Pavol Jozef Šafárik University in Košice, Slovakia

The Barcelona Conference on Education 2022
Official Conference Proceedings

Abstract
The research aim was to verify the efficiency of a metacognitive strategy called Post-Test Reflection (PTR), implemented into Chemistry Teaching Students' Training. This research was performed in the 2020/2021 academic year during a course in Chemistry Didactics. The sample consisted of 22 Chemistry Teaching students in the 1st year of their Master study. First, students took a test focused on selected topics of general chemistry didactics. The results showed that students had superficial knowledge and misconceptions, which was related to their learning methods. Students were asked to review the test questions at home in order to identify the errors they made, explain why these errors occurred, and how they could be removed, which promoted deeper understanding of the subject matter. At the end of the semester, students completed their course in Chemistry Didactics by taking a second test and an oral examination. The PTR self-assessment metacognitive strategy showed efficiency. PTR promoted the development of cognitive understanding in the students, which led to changes in their learning strategies. After PTR, the students proceeded to achieve better academic results as confirmed by the results of the second test as well as the oral examination taken during the Chemistry Didactics course. The research showed that metacognition promoted "deep understanding" and increased students' motivation to learn.

Keywords: Metacognition, Metacognitive Strategies, Self-Assessment, Post-Test Reflection, Chemistry Teaching Students

1. Introduction

Formative assessment (FA) is a process, which is planned and continuous; based on regular interactive evaluation of students' work provides feedback on students' learning and their progress towards achieving the determined goals. It also helps identify what needs more attention and what steps need to be taken to achieve progress. Therefore, FA contributes to an overall learning improvement (CCSSO, 2018).

The goal of FA is to obtain information on students' learning, i. e. reveal, and diagnose shortcomings, mistakes, difficulties and their reasons (Cowie & Bell, 1999).

FA allows the students to develop their cognitive as well as metacognitive strategies. Formative assessment classroom techniques (FACTs) can be used to identify preconceptions, engage students, activate their thinking, stimulate scientific discussion, promote metacognition, self-assessment and much more. Many of these FACTs initiate the use of metacognitive skills and promote deeper student thinking. This study investigates the effect of FACTs implementation on the development of students' metacognitive skills.

2. Metacognition and Metacognitive Strategies

The Dictionary of Pedagogy (Průcha, Walterová, & Mareš, 2008) defines metacognition as one's ability to plan, monitor, and evaluate the processes through which they learn. This conscious activity allows one to realize how they proceed when they are learning about the world. Everyone has the ability to perform metacognition and its strategies, which improves as the person ages. Education is an important factor as students learn through completion of assignments and the subsequent feedback. This ability significantly develops when schooling starts (Mesárošová, Bavoľár & Slavkovská 2018).

In terms of education, the term metacognition refers to the students' ability to analyse their own learning and control it efficiently (Flavell, 1979). The metacognitive ability determines the students' learning performance. It allows students to investigate their own learning processes, design the best learning procedures, influence their own interests and attitudes to the given task, problem, course, etc. (Wang, Haertel, & Walberg, 1993).

Metacognition plays an important role in academic performance as well. Extensive research on metacognitive and cognitive strategies has shown that learning about learning and thinking can help student improve their higher-order cognitive operations such as application, analysis, evaluation, and creativity (Hattie, 2009).

If a teacher wants to help students develop metacognitive strategies, they must be able to reflect on their own teaching process in the first place. Teachers are supposed to undergo life-long learning and constantly improve their knowledge and skills as well as their teaching practice in order to help students achieve the best academic performance possible (DESE, 2013).

In terms of metacognitive learning, students are active and in control of the process. Metacognitive learning transforms students into experts who can not only explain, but also analyse the knowledge, plan the related activities, verify their usefulness, and implement them in practice.

However, metacognitive strategies are rarely used in teaching. Students learn the subject matter, but little time is invested into teaching them how to learn. Students forget factual information quite quickly. In 2–3 years after leaving the school, they forget about 60% of it. Nevertheless, any further education or career require the individual to constantly deal with new problems that need to be solved, new information that needs to be comprehended, and new tasks that need to be completed. If we teach students how to learn, it can help them prepare for these future challenges (Mcelwee, 2009).

Metacognition in education offers the following benefits: improved teaching efficiency, improved self-study abilities; improved ability to track one’s own progress, which allows the person to take control of their own learning during classes and outside school, and improved endurance. Identifying which strategies led to success and failure respectively improves student endurance in terms of self-improvement (Lovett, 2013; Mcelwee, 2009).

Self-assessment is one of the metacognition strategies. Through self-assessment, students can identify their progress on the way to their goal. They learn to take control of their own learning. Self-assessment is one of the most important skills for their future career and life-long learning (Taras, 2010; Wride, 2017).

Students play the key role in helping students develop self-assessment skills.

Besides the (revised) Bloom’s taxonomy, there is also the new taxonomy of educational goals created by Marzano and Kendall (2007). In this case, focus has been paid to the student. In accordance with their taxonomy, students are to ask the following questions:

1. What is my learning goal? What new things will I learn? Here I monitor my own personal goals and benefits.
2. What usually helps me to learn? How have I handled a similar task in the past? In this case, I monitor my learning process.
3. What is not clear to me? What is it that I don't understand? Which part of the subject matter do I not understand? By asking these questions, students monitor the extent to which they understand the material.
4. What other information do I need to get? Where can I get the information I need? Students reflect on their future learning steps.

The formulation of the basic metacognitive strategies as formative assessment strategies can draw on the following questions, which help teachers as well as students to plan, teach, and learn: Where am I heading? Where am I right now? How do I achieve my goal? How to proceed? (Atkin, Black, & Coffey, 2001; Chappuis, 2009; Hattie, 2003; Hattie & Timperley, 2007).

3. Research Methodology

Implementation of Post-Test Reflection (PTR) into Chemistry Teaching Students’ Training

The research goal was to verify the efficiency of metacognitive strategies (i.e. self-assessment) implemented in university teaching.

The research questions were defined as follows:

1. Does self-assessment performed using PTR actually influence the development of conceptual understanding in chemistry teaching students?
2. Does self-assessment performed using PTR actually change the learning strategy in chemistry teaching students?

This research was performed in the 2020/2021 academic year during a course in Chemistry Didactics at P. J. Šafárik University in Košice, Slovakia.

The research sample consisted of 22 chemistry teaching students in the 1st year of their Master study.

Figure 1 presents the stage of research design.

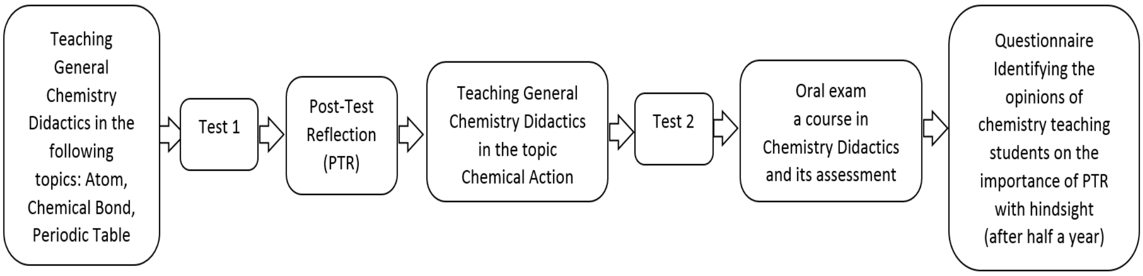

Figure 1: Stages of Research Design

Research Implementation Procedure

In the 2020/2021 academic year, chemistry teaching students completed 2 tests within the course in Chemistry Didactics. The first test aimed to check their knowledge of general chemistry didactics in the following topics: the atom, chemical bond, periodical table of elements. Test 1 showed that students had superficial knowledge and misconceptions, which was related to their learning methods. Students found it difficult to explain basic information taught at grammar school chemistry classes such as the structure of water molecule, benzene, periodicity of ionisation energies, electronegativity, the point of Rutherford's experiment, etc. The unsatisfactory results may have been influenced by the fact that remote teaching was used for two years prior (2019–2020). Students mostly memorised the content of the materials (provided on site or online). After test 1, students argued as follows: "We are not used to learn with deep understanding. During other classes, we are simply required to reproduce the subject matter and the teacher will correct the misconceptions." It was important to explain and convince them that as future chemistry teachers, they need to develop a deep understanding of the subject matter they would be teaching. As future teachers, they have to explain the subject matter fluently and without misconceptions.

Therefore, the Evaluation of the Post-Test Reflection (PTR) as a metacognitive strategy was implemented in order to improve their learning. Students were given back their test 1 and instructed to analyse their answers at home to identify the misconceptions, supplement and enhance their knowledge through study of further sources, and realise what they did wrong in terms of learning. Students were instructed to consider how to improve their learning and identify whether a change to their learning strategy is necessary to enhance their understanding.

The students' task was to correct their test 1 answers and answer the following questions in writing:

1. What seemed difficult about this task?
2. What will I do to improve my understanding of this problem?
3. Do I have to change my learning strategy? How do I change my learning strategy?

At the end of the 2021 summer semester, students took test 2 focused on chemistry didactics, specifically the chemical action topic.

Subsequently, students took an oral examination in Chemistry Didactics.

4. Results

4.1 Evaluation of the Post-Test Reflection (PTR)

The answers of the chemistry teaching students were grouped and coded for the purpose of frequency/quantity calculations.

Note: Some chemistry teaching students provided multiple reasons.
Below is a sample of the PTR evaluation of selected task of Test 1 (see Tables 1 to 3).

Question 1: What seemed difficult about this task?

Code meaning	**Number**
DF Difficulty formulating the correct answer	11
DC Difficulty comprehending the task instructions	10
LK Lack of input knowledge resulting from the previous learning strategy	8
DP Difficulty providing examples	6
NO No answer	5
LT Lack of time to complete the task	3

Table 1: The Number of Codes Assigned to Question 1

Question 2: What will I do to improve my understanding of this problem?

Code meaning	**Number**
DP I will learn with more comprehension (deeper learning)	13
MR I will use more resources such as videos and animations	11
NO No answer	2
LT Lack of time to complete the task	1

Table 2: The Number of Codes Assigned to Question 2

Question 3: Do I have to change my learning strategy?

Yes	Probably yes	No
12	5	5

Table 3: The Number of Answers to Question 3

How do I change my learning strategy?

- By studying more resources such as animations, I should also review the seminar materials.
- By using more imagination and allocating more time to studying.
- By revising aloud. Some chemistry teaching students realized they had been learning superficially by memorisation and if they are to explain the subject matter to their students in the future and provide specific examples, they have to actually comprehend the subject matter themselves.
- To improve their understanding of the subject matter, most chemistry teaching students need to revise it.

4.2. A Comparison of Test 1, Test 2, and Oral Exam Results in the Chemistry Didactics Course

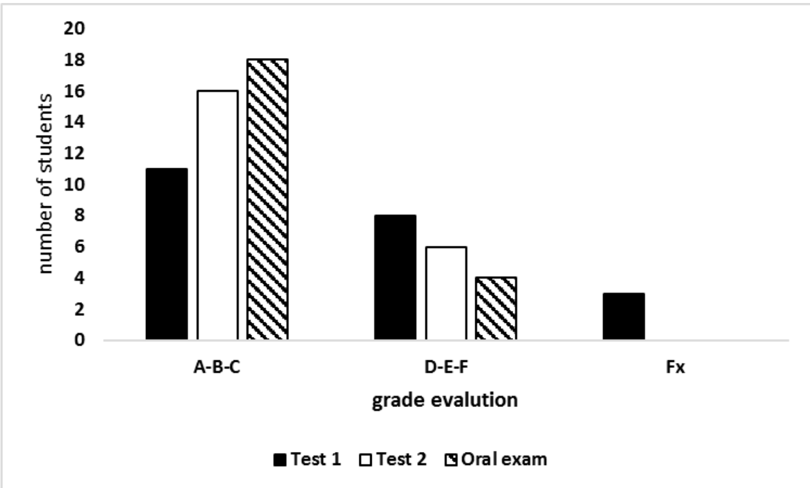

Figure 2: A Comparison of Test 1, Test 2, and Oral Exam Results in the Chemistry Didactics Course

The "A, B, C, D, E, Fx" grading scale was divided into 3 groups for the purpose of simplification.

4.3. The Importance of Post-Test Reflection (PTR) with Hindsight (half a year) – Chemistry Teaching Students' Opinions

Six months after the research, the students filled out a short questionnaire with two questions.

Question 1: Did you find the Post-Test Reflection (PTR) during the Chemistry Didactics course meaningful in any way? If yes, please specify.

Question 2: Do you consider the Post-Test Reflection (PTR) meaningful for you as a future chemistry teacher in the long term?

All 22 chemistry teaching students responded positively.

The chemistry teaching students reported the following positive aspects of PTR:

- Analysing one's own learning process
- Improved understanding upon revision of the subject matter
- Gained more knowledge upon revision of the subject matter
- Identification of weaknesses and knowledge gaps
- Focus on the misconceptions

5. Discussion and Conclusions

The PTR self-assessment metacognitive strategy showed efficiency. PTR promoted the development of cognitive understanding in the chemistry teaching students, which led to changes in their learning strategies. After PTR, the chemistry teaching students proceeded to achieve better academic results as can be seen in the results of Test 2 as well as the oral exam taken during the Chemistry Didactics course. With hindsight (half a year), the chemistry teaching students evaluated the PTR strategy positively. It made them think about their attitude to learning, level of knowledge, and their own learning methods, i.e., students reconsidered the efficiency and usefulness of their methods. The experience gained is likely to be useful for them in practice when they start teaching themselves.

The research showed that metacognition promoted "deep understanding" and motivated students to learn. These findings are in lines with the following studies:

–Wang, Haertel, and Walberg (1990) have claimed that supporting the development of metacognition is an efficient way to help students succeed in their university studies. Students with strong metacognitive skills are able to learn more and perform better at school. Students with well developed metacognition can identify the concepts they do not understand and select suitable strategies to deal with them.

–Veenman, Van Hout-Wolters, and Afflerbach (2006) have pointed out that appropriate metacognition level can compensate for students' cognitive limitations.

–Ur-Rahmana et al. (2010) have investigated the impact of metacognitive awareness on student performance. In this case, metacognitive awareness significantly correlated with student performance. Science students with high metacognitive awareness performed better in the test.

Further research should focus on reading comprehension in chemistry teaching students as this skill is also closely related to the learning skills (see e.g. Pintrich 2002).

Acknowledgements

This paper was supported by the KEGA No. 004UPJŠ-4/2020 “Creation, Implementation, and Verification of the Efficiency of Digital Library with the Formative Assessment Tools for Science, Mathematics, and Informatics at Primary Schools” grant.

References

Atkin, J. M., Black, P., & Coffey, J. (2001). *Classroom assessment and the national science standards.* Washington, DC: National Academies Press.

CCSSO. (2018). *Revising the definition of formative assessment.* Washington, DC: Council of Chief State School Officers.

Chappuis, J. (2009). *Seven strategies of assessment for learning.* Boston: Allyn & Bacon.

Cowie, B., & Bell, B. (1999). A model of formative assessment in science education. *Assessment in Education: Principles, Policy & Practice, 6*(1), 101-116.

DESE (2013). *Teacher Standards. Missouri Department of Elementary and Secondary Education.* Retrieved from https://dese.mo.gov/media/pdf/oeq-ed-teacherstandards.

Flavell, J. H. (1979). Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry. *American Psychologist, 34*(10), 906-911.

Ganajová, M., Guniš, J., Ješková, Z., Kireš, M., Laufková, V., Lešková, A., Lukáč, S., Orosová, R., Sotáková, I., Szarka, K., & Šnajder, Ľ. (2022). *Formatívne hodnotenie a jeho implementácia do výučby prírodných vied, matematiky a informatiky.* Bratislava: Wolters Kluwer.

Hattie, J. (2003). Teachers make a difference: What is the research evidence? *Building Teacher Quality: What does the research tell us?* (pp. 1-17). Melbourne: Australian Council for Educational Research (ACER).

Hattie, J. A. C. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement.* New York, NY: Routledge.

Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81-112.

Lovett, M. C. (2013). Make exams worth more than the grade: Using exam wrappers to promote metacognition. In Kaplan M., Silver N., LaVague-Manty D., & D. Meizlish (Eds.), *Using reflection and metacognition to improve student learning: Across the disciplines, across the academy* (pp. 18-52), Sterling, VA: Stylus.

Marzano, R., & Kendall, J. (2007). *The new taxonomy of educational objectives* (2nd ed.). Thousand Oaks, CA: Corwin Press.

McElwee, S. (2009). *Metacognition for the classroom and beyond: Differentiation and support for learners.* Special Education Support Service.

Mesárošová, M., Bavoľár, J., & Slavkovská M. (2018). *Kognitívne, metakognitívne kompetencie a sebaregulácia v kontexte motivácie.* Košice: Univerzita Pavla Jozefa Šafárika.

Pintrich, P. R. (2002). The role of metacognitive knowledge in learning, teaching, and assessing. *Theory Into Practice, 41*(4), 219-225.

Průcha, J., Walterová, E., & Mareš, J. (2008). *Pedagogický slovník.* Praha: Portál.

Taras, M. (2010). Student self-assessment: Processes and consequences. *Teaching in Higher Education, 15*(2), 199-209.

Ur-Rahman, F., Jumani, N. B., Chaudry, M. A., Chisti, S. H., & Abbasi, F. (2010). Impact of metacognitive awareness on performance of students in Chemistry. *Contemporary Issues in Education Research (CIER), 3*(10), 39-44.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning, 1*(1)*,* 3-14.

Wang, M. C., Haertel, G. D., & Walberg, H. J. (1990). What influences learning? A content analysis of review literature. *Journal of Educational Research, 84*(1), 30-43.

Wang, M. C., Haertel, G. D., & Walberg, H. J. (1993). Towards a knowledge base for school learning. *Review of Educational Research, 63*(3), 249-294.

Wride, M. (2017). *Guide to self-assessment.* Academic Practice, University of Dublin, Trinity College, and LLAF resource.

Contact email: maria.ganajova@upjs.sk