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Małgorzata Krzeczowska

How Students – Future Teachers Identify themselves with the Issue of Organic Reaction Mechanisms in the Context of Chemistry Lesson Carried out at Schools

Organic chemistry involves thousands of different reactions enabling the synthesis and transformation of millions of compounds. The key to understanding this extremely important branch of chemistry is to learn about the mechanisms of organic reactions that describe the details of the reaction at every stage of chemical transformation.

Richard A. Jackson: Mechanizmy reakcji organicznych, Wydawnictwo Naukowe PWN, 2007.

Theoretical approach: In Poland a subject-matter (CK & PCK), pedagogical (PCK & PK according to Schulmann, 1986) and formal preparation is required from each teacher, including the pre-service teachers training PSTs (Burewicz & Gulińska, 2002).

During the substantive preparation, all contents and issues to be brought up during a lesson should be determined, together with their purposes and order, keeping in mind the principles of teaching. The methodical preparation requires finding an answer to the question of how the particular lesson should be carried out – which teaching methods and didactic (teaching) aids should be applied. Teachers' and students' actions should be determined, together with forms and methods of control and homework. On the other hand, the organizational preparation is connected with the workplace preparation and necessary didactic (teaching) aids.

In the author's opinion, substantive preparation is considered to be the most important component of teacher's education. Being aware that there are also distinct opinions, the author nevertheless would like to underline the huge importance, weight and complexity of subject substantive preparation and the enormity of the problems related to it. Whatsoever, it does not mean that she calls into question, does not recognize the value of a teacher's personality traits, the knowledge of contemporary, universal teaching theories, particularly concerning creative approach to teaching. Because who will pass on thorough and reliable knowledge to students? This will only be the teacher, who possesses it, but who will also teach their students to think correctly, analyze and solve a complex task, therefore the teacher who herself has the well-established capacity of logical thinking, noticing biological-chemical-physical processes taking place in everyday situations in the world around and who can create

and solve such tasks and problems. Good knowledge of the subject taught requires constant broadening of possessed knowledge. Schools cannot handle outdated knowledge; they should also track the progress of science. Therefore, a teacher also has to update earlier acquired knowledge and confront their information with the current state of knowledge (Buchcic, 2014).

The ability to evaluate one's own self-esteem, level of expertise and didactic-pedagogical-organizational skills of students, future teachers – head teachers is not without significance.

The context and purpose of the framework: At the Faculty of Chemistry of the Jagiellonian University, students have the opportunity to obtain permission to teach chemistry at primary and secondary school level by participation in pre-service teachers training. The programme of pre-service teachers training includes a school-based course.

Based on long-term experiences of the author who conducts this course, her observations and reflections, there are several subjects, issues repeating year on year, which are unwillingly realized by students, who find them difficult. The issue related to reaction mechanisms in organic chemistry is definitely least liked and friendly to the students.

It is obvious that reaction mechanisms are a fundamental part of the study of organic chemistry. J. Brent Friesen (2008) wrote: "Organic reactions in introductory organic chemistry courses are most commonly taught with a mechanism-based approach to the understanding of molecular reactivity." Some students' problems in this area are presented and discussed in many articles (e.g Anzovino and Lowery Bretz, 2015; Sevia, Bernholt, Szteinberg, Auguste and Pérez, 2015).

Research methodology: Survey questionnaire developed especially for the needs of the conducted research was a research tool. It consisted of 4 questions concerning students' feelings about their preparation for conducting classes associated with reaction mechanisms, as well as specifying difficulty level in explaining specific notions to school pupils. The catalogue of concepts suggested in the survey was chosen on the basis of the factsheets that appeared more frequently in accessible graduation sheets (old and new formula) on the website of Central Examining Board¹. The interviewees' task was to identify difficulties in the explanation of given notions on a 5-point Likert scale. The question about chemistry exam grade was included in the questionnaire form.

The study enrolled faculty students representing Chemistry and Environmental Protection Departments. The research was carried out in the winter semester in the academic year in a 3-year period – from 2017 to 2019. Student participation was voluntary and anonymous.

The questionnaire of the survey was filled in by 69 students. A vast majority of the surveyed were women (n=51), what constituted 74%. 91% of the respondents were chemistry students.

Results and discussion: A group of 69 students were asked to complete the questionnaire, which was designed to identify factors that determine the decision

¹ <https://cke.gov.pl/egzamin-maturalny/>

to conduct lessons on the mechanisms of chemical reactions in organic chemistry in high school classes with extended curriculum. To determine these factors logistic regression was employed based on binominal distribution. Outcome variable – the decision to conduct lessons – was subjected to logistic regression with eight predictors summarized in Table 1.

Table 1. Design of survey taken by group of students.

Variable	Type	Values/coding	Relevant question from questionnaire
the decision to conduct lessons	dichotomous	Yes / No	Would you decide to conduct the lesson on the mechanisms of chemical reactions in organic chemistry in upper secondary school in the class of extended curriculum?
organic chemistry exam mark	continuous	2, 3, 4, 5	
year of study	continuous	1, 2, 3, 4, 5	
type of higher education institution	dichotomous	university / technical university	
sex	dichotomous	female / male	
university specialization associated with organic chemistry	dichotomous	Yes / No	What is your academic specialization?
personality of the person being surveyed	dichotomous	Yes / No	Do you like challenges?
assessment of the difficulty of issues related to reaction mechanisms at upper secondary school level	categorical	-2, -1, 0, 1, 2	Would you consider issues related to the reaction mechanisms in organic chemistry at the secondary school/university level as: very difficult, difficult, no opinion, easy, very easy?
assessment of the difficulty of issues related to reaction mechanisms at higher education institution level			

In order to indicate the factors influencing the decision the logistic regression model was chosen based on the Akaike information criterion. The application of this approach indicated that the decision to conduct lessons is best explained by two statistically significant variables, i.e. organic chemistry exam mark and assessment of the difficulty of issues related to reaction mechanisms at higher education institution level. The logistic regression model is further detailed in Table 2. The chi-square value is highly significant indicating that the model fit is good.

Table 2. Logistic regression model for predicting the decision to conduct lessons on the mechanisms of chemical reactions in organic chemistry in high school classes with extended curriculum.

	β (SE)	95% confidence intervals for odds ratio (OR)		
		lower	OR	upper
intercept	-3.55* (0.78)	—	—	—
organic chemistry exam mark	0.80* (0.21)	0.41	2.23	1.22
assessment of the difficulty of issues related to reaction mechanisms at upper secondary school level	0.59* (0.16)	0.28	1.81	0.93
model χ^2 (2) = 36.4, $p < 0.001$ R^2 (Hosmer-Lemeshow) = 0.13 n = 200 * $p < 0.001$				

It seems that both the organic chemistry exam grade, as well as assessment of the difficulty of organic chemistry issues at high school level may determine a potential candidate to conduct the lesson on reaction mechanisms. Consent to conduct lessons is favoured when student achieves better results in organic chemistry exam and considers high school organic chemistry material as easy or very easy. Assessing the level of difficulty of the high school material in such a way (probably from their own experiences) students are confident that they will cope with conducting lessons regarding this material, and their exam marks serve as an reinforcement. Other variables, as they are not included in the model, can be considered insignificant.

Students were also asked to assess the level of difficulty of several organic chemistry issues in scale of five statements: very easy, easy, no opinion, difficult and very difficult. The question was answered by 113 students. Results were analysed with respect to a group of student deciding to conduct a lesson and a group of students taking different decision. For each of the organic chemistry topics relevant answers were counted and the final result was given as the difference of these values for both groups of students. Resulting plot, along with hierarchical cluster analysis of organic chemistry topics (with Euclidean distance measure and complete linkage agglomeration method), is presented in Figure 1.

Interestingly, it seems that the greatest disagreement between students coming from two different groups is related to the fundamental concepts of organic chemistry when reaction mechanisms are a topic at hand, namely: electrophile, nucleophile and radical. Cluster analysis finds these topics closely related based on students responses. Students deciding to conduct lessons find these topics very easy whereas other students are inclined to assess them as easy. Both groups of students do not disagree when the concepts of carboanion and carbocation are deemed to be very difficult. Supervising teacher of a student's pedagogical training might consider deepening material related to electrophile, nucleophile, radical, carboanion, carbocation, radical and carbocation creation topics. Cluster analysis also identifies

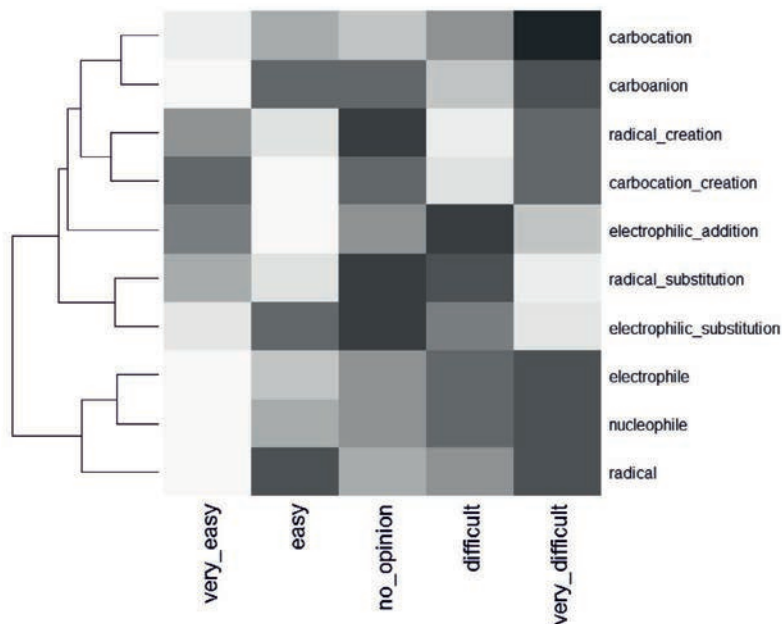


Figure 1. Differences in understanding the difficulty of the organic chemistry concepts for students who decide and not decide to conduct lessons. Brighter colour corresponds to a greater degree of disagreement between the two groups of students.

groups of topics considered as coming from the same thematic units, notably: radical and electrophilic substitution reactions, aforementioned cluster of electrophile, nucleophile and radical as well as group of carbocation and radical creation processes.

Each of the surveyed students was asked to list main reasons behind their choice whether to conduct or not the lesson. There is a noticeable variation in the responses of two groups of students. Students expressing the content to conduct lessons highlight their ambition, curiosity and possible satisfaction. It is worth emphasizing that these students stress that learning reaction mechanisms at the secondary school level is extremely valuable for students. In this way, secondary school student can reach to the heart of organic chemistry and can avoid the popular learning letter relying on the memorization of rigid list of syntheses and characteristic reactions of many types of organic compounds. As strengths, which favour the choice taken, students find the courage, expertise, thoroughness, commitment to work with children and previous experience. Students who chose not to conduct lessons also have been asked to state reasons behind their decision. These reasons relate primarily to concerns linked with stress associated with public speaking, lack of interest in teaching as well as a lack of understanding of the subject. This last reason is reflected in poor marks for organic chemistry exam. Students choosing to conduct lessons indicate the two areas of decision-making about a matter at hand: personality traits and belief in the merits of the students' need to be familiarized with the subject of organic chemistry reaction

mechanisms. Students not taking this decision point out the lack of both pedagogical and substantive competences.

Perhaps the reason for such a situation is also the fact that teachers unknowingly make mistakes and consider the knowledge contained in school textbooks to be irrefutable. This, combined with students' little experience in learning techniques, interpretations of scientific concepts oversimplified for didactic purposes as well as the lack of appropriate analogies and associations, produces the observed effect. It is obvious that active learning approaches, proper activities and a need to integrate them with teachers' classroom activities is essential for effective chemistry lessons.

Therefore, it seems appropriate to conduct further research among teachers the aim of which would be to check how they teach organic reaction mechanisms, which active techniques they use, and how they stimulate students to develop strategies and models helpful in learning and problem solving as well as how they encourage students to use different models which can help them to overcome learning difficulties in this topic.

Thanks to the participants of the survey.

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Appendix:

The survey is anonymous. I am kindly asking you to fill it reliably. Thank you.

Sex F/M Year of study

First level studies, current/planned panels

Second level studies, current/planned specialization

Grade from the organic chemistry exam:

1. I consider issues related to reaction mechanisms in organic chemistry at university level to be:
Very easy Easy I have no opinion Difficult Very difficult
2. I consider issues related to reaction mechanisms in organic chemistry at secondary school level to be:
Very easy Easy I have no opinion Difficult Very difficult
3. Would you decide to give a lesson on the mechanisms of chemical reactions in organic chemistry in upper secondary school with an extended chemistry curriculum? YES/NO

If the answer is YES:	If the answer is NO:
<ul style="list-style-type: none"> • Write down your strengths: • Give the main arguments in support of your answer YES: 	<ul style="list-style-type: none"> • Write down weaknesses, the fears that accompany you • Give the main arguments in support of your answer NO:

4. In your opinion, specify the level of difficulty (in explaining the following terms to school students):

	Very easy	Easy	I have no opinion	Difficult	Very Difficult
Electrophil					
Nucleophile					
Radical					
Carbocation					
Carbanion					
Formation of carbocation					
Formation of radical					
Electrophilic substitution					

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Abstract

Lesson is the basic unit in the teaching and learning process. Both the teacher and students participate in it, therefore they all should be prepared for the class. The requirement of good substantive preparation for a lesson is not only empowered legally, but it also results from

teacher's own reflection on the improvement of educational process in the context of its effectivity. Recognition of a future teacher in terms of their personal cognitive preferences and professional knowledge is key for the improvement of teaching quality. The main aim of the study was to find out factors that determine the students' decision to conduct lessons on the mechanisms of chemical reactions in organic chemistry at upper secondary school level. For this purpose the results from survey were analysed.

Keywords: education, pre-service teacher training, organic reaction mechanisms

dr Małgorzata Krzeczowska

Department of Chemical Education, Faculty of Chemistry, Jagiellonian University
in Krakow

email: malgorzata.krzeczowska@uj.edu.pl

ORCID: 0000-0003-0913-709X