Research Article

Zoltán Murányi and Mihály Kovács*

Using green and sustainable chemistry practical activities in Hungarian classrooms: barriers and opportunities

https://doi.org/10.1515/cti-2025-0056
Received June 12, 2025; accepted August 11, 2025; published online October 24, 2025

Abstract: This study presents results from the IUPAC Teacher Survey on Practical Activities in Hungary. In this article, we focus on issues related to the frequency of use of green and sustainable chemistry experiments, what promotes their use and what barriers inhibit it. The sample had a size of 169, representing ~5 % of Hungarian chemistry teachers. The majority of participants had a bachelor's or master's degree and were experienced. Most of them reported using hands-on activities in their work once a month or a few times a year, which was less frequent than the global average, and they also used green and sustainable chemistry experiments less frequently than the global average. The most frequently reported barriers were lack of time and lack of laboratory equipment and chemicals, similarly to the European results. Other barriers mentioned were fear of accidents and overcrowded classrooms. Critical thinking and problem-solving skills were reported as the main reasons for choosing GSC activities, while their connection with local environmental issues was considered less important by the respondents. These results will help us to improve our teacher training and modify its priorities to encourage high school chemistry teachers to use more experiments in their practice.

Keywords: practical; activities; demonstrations; green and sustainable chemistry; experiments; teaching practice

1 Introduction

This study is about the Hungarian results of IUPAC Teacher Survey on Practical Activities (Project No.: 2023-002-2-050). In this project, the term "practical activity" means "any chemical reaction, experiment or demonstration performed in the classroom or laboratory by students or a teacher".[1] Practical activities are useful tools in chemistry education, and can be applied for different pedagogical purposes, although their use is sometimes questioned.[2,3] Nonetheless, studies show that both knowledge and attitude towards chemistry can be influenced in a positive way with practical activities.[4,5]

There has been research on the "best practice" in laboratory work in secondary chemistry education, which has been shown to be guided research.[6] However, no data is available on how often, with what content and for what reasons teachers choose practical activities. One of the aims of the survey is to explore this.[1]

Besides, there are some barriers to the widespread use of practical activities in schools, especially in the case of inquiry-based learning, since teachers need knowledge, skills and resources to be able to use practical activities effectively in their everyday work.[7] Thus, both pre-service and in-service teachers need training to enhance their competencies.[8] It should be emphasized that resources here mean not only teaching materials but also laboratory

Zoltán Murányi and Mihály Kovács contributed equally to this work and share first authorship.

***Corresponding author: Mihály Kovács**, Observatory and Science Experience Center, Eszterházy Károly Catholic University, Eszterházy sqr. 1., H-3300 Eger, Hungary, E-mail: kovacs2.mihaly@uni-eszterhazy.hu. https://orcid.org/0009-0000-6293-654X
Zoltán Murányi, Chemistry Institution, Eszterházy Károly Catholic University, H-3300 Eger, Hungary. https://orcid.org/0009-0001-1445-8042

equipment and reagents.[9] Thus, the other goal of this project is to reduce these barriers by collecting good practices and offering activities requiring few resources.[1]

2 Literature review

2.1 Green chemistry

The world's first green chemistry program, the Alternative Synthetic Pathways Grant Program, was launched in 1991 by the US Environmental Protection Agency (EPA). In Europe, the first green chemistry program was launched in 1993 in Venice by 30 universities. The rapid expansion of this area of chemistry is also driven by the realization that environmentally and health-friendly products and technologies are the most cost-effective in the long term.[10]

Anastas and Warner[11] summarize the objectives of this area of chemistry in 12 points, which are mainly focused on reducing or eliminating the production and use of substances that are hazardous to the environment. This list is also available in Hungarian,[10] and a link to them was shared with the teachers involved in this research to help them answer the questionnaires properly.

2.2 Sustainable chemistry

The most cited definition of sustainable development comes from the 1987 UN report "Our Common Future". This states that sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs."[12] Thus, we can say that "sustainable chemistry should use resources, including energy, at a rate at which they can be replaced naturally, and the generation of waste cannot be faster than the rate of their remediation."[13]

However, this is a complex issue, which is why 17 Sustainable Development Goals (SDGs) were set at the 2015 UN Summit, with a further 169 sub-goals.[14,15] Therefore, sustainable chemistry can be understood as chemistry that addresses SDGs.

We should underline that green chemistry and sustainable chemistry are two different concepts, something can be green but not sustainable, or sustainable but not green.[13] Hence, this project uses the concept of green and sustainable chemistry (GSC), which "refers to chemistry, that satisfies the principles of green chemistry along with the SDGs"[1] Since GSC can offer solutions to many global environmental problems, its integration into education is crucial, as well-trained people are needed to develop and implement innovations: chemists, workers, policy makers and citizens.[16]

2.3 Green and sustainable chemistry in Hungarian education system

Recognizing the importance of the GSC, several countries have already integrated its principles into their curricula.[17] Sustainability education was already linked to chemistry in the first Hungarian curriculum in 1995,[18] and it remains so in the current 2020 curriculum. On the one hand, the current curriculum declares the students' commitment to sustainability as an educational goal, on the other hand, it states that without a solid knowledge of chemistry, our lives cannot become sustainable. The 2012 curriculum prescribed the teaching of the efforts, importance and principles of green chemistry,[19] nevertheless the current curriculum only mentions it implicitly when referring to the chemical aspects of global problems, giving the production of new materials as an example.[20]

Not only the curriculum requirements emphasize the importance of environmental education, but teachers must also demonstrate competence in environmental education in order to progress in the Hungarian Teacher Qualification System.[21] Therefore, green and sustainable chemistry are parts of the requirements for teacher training in Hungary,[22] and since one of the authors of this article is involved in preparing the country's future training and graduation requirements, we can share that the plan is to increase their weight from four to six credits.

In connection with this IUPAC project, we should also highlighting that the Hungarian curriculum encourages teachers to teach chemistry through easy-to-do experiments.[20] Nevertheless, there is also a research gap at international level regarding teachers' use of GSC practical activities.[1]

Due to the space limitations of a paper, we can only address some questions from the survey. In this article, the focus is on the questions of the survey related to the frequency of use of green and sustainable chemistry experiments, what helps and what barriers prevent their use.

3 Sample and methods

This paper analyses the responses in Hungary to the first four pages of the questionnaire presented by Delaney et al.[1] This survey was mainly based on an article by Abrams and Millar.[23] It started with an introductory page describing the project and asking for an indication of willingness to participate. The first page contained demographic questions, the second page had questions about practical activities in general, the third page asked about GSC practical activities, and the fourth page had open-ended questions about exactly what GSC practical activities teachers use in their work.

This paper compares the results with the snapshot of the international survey presented at 16th ECRICE.[24] The questionnaire has been shared on the largest chemistry teacher Facebook group in Hungary and has also been sent via email to chemistry teachers in their schools through the school governor. A total of 172 teachers opened the questionnaire, three of them did not agree to participate in the survey, making a final sample size of $N = 169$. This is roughly 5 % of the Hungarian chemistry teachers, as there were 3,588 in 2022, and their number is slowly decreasing.[25]

The highest level of education was a bachelor's degree (or equivalent) for 41, a master's degree (or equivalent) for 123 and a doctorate for five participants. 153 of them had chemistry teacher training, the others did not, however, there is a chemistry-related subject called 'natural science' in Hungary, which was also part of the scope of this research. As shown in Table 1, majority of the respondents were experienced chemistry teachers.

Table 1: Participants' educational experience.

	Experience as a teacher		Experience as a chemistry teacher	
	Count	Percentage (%)	Count	Percentage (%)
First year of teaching	5	3.0	9	5.3
2–5 years	11	6.5	21	12.4
6–15 years	30	17.8	32	18.9
16–30 years	61	36.1	57	33.7
More than 30 years	61	36.1	49	29.0

4 Results

4.1 Descriptive statistics

Teachers were asked to rate the frequency of the different activities on a Likert scale (5 = never, 4 = few times per year, 3 = once per month, 2 = once per week, 1 = more than once per week). Table 2 shows that participants use practical activities the least frequently; in fact, 11.8 % stated that they never use such activities in their work.

Teacher demonstrations are performed significantly more often, with only one respondent stating that they never demonstrate such experiments. Videos of chemistry experiments are used with similar frequency, with only three participants marking the "never" option in this case.

Figure 1 shows that among the barriers that prevent teachers from using practical activities more often in the classroom, the lack of time in class received the highest number of marks, while the lack of laboratory equipment and chemicals was the second most common and the lack of time to prepare experiments outside class was the third. Knowledge of appropriate experiments was the least mentioned.

On average, 29 % of Hungarian respondents' chemistry experiments are related to the field of GSC, with a median = 22 %, a lower quartile of 14 % and an upper quartile of 40 %. Teachers were asked to rate on a Likert scale how important various factors were to them when choosing a GSC practical activity (0 = not at all important, 3 = moderately important, 5 = very important), the descriptive statistics are provided in Table 3. Respondents considered the least important aspect to be that the experiments should be clearly linked to a local environmental problem; the other factors received similar ratings. GSC experiments being more interesting for students and practical activities as a way of introducing GSC were the same, while the development of critical thinking and problem-solving skills were ranked as the most important.

Table 2: Frequency of different activities in teaching practice (5 = never, 4 = few times per year, 3 = once per month, 2 = once per week, 1 = more than once per week).

Frequency of…	Mean	Mode(s)
Practical activities	3.39	4
Teacher demonstration	2.72	3
Video of chemistry experiments	2.67	2 and 3

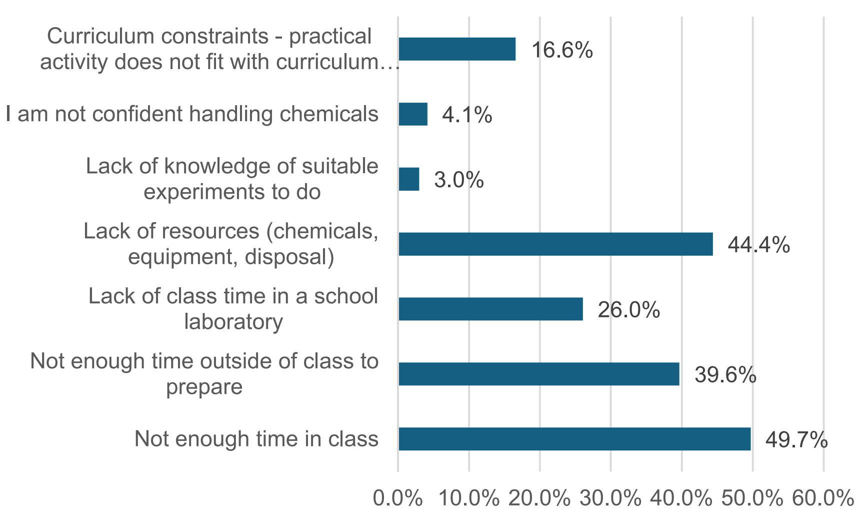

Figure 1: Frequency of barriers to more frequent use of practical activities in teachers' responses.

Table 3: The importance of various factors in selecting GSC practical activities.

Factor	Mean	Median	Mode
The practical activity is clearly linked to local environmental issues	3.1	3	3
Students find green chemistry and sustainability issues and topics engaging	3.7	4	4
Practicals are a way to introduce green chemistry and sustainability through a hands-on activity	3.7	4	4
Students have opportunities to develop critical thinking and problem-solving skills related to green and sustainable chemistry	3.8	4	4

4.2 Statistical tests[26,27]

Mann-Whitney U tests were calculated to gain a better understanding of the effect of time on activity selection, as this seemed to be the most important issue for our respondents, but we limited our analysis to the three most common activities (practical activity, teacher demonstration, or video experiment). This was possible because the questionnaire covered three different aspects of the time factor. Table 4 shows that there was only one significant difference: teachers who indicated the barrier of "not enough class time" used significantly fewer practical activities in their work.

Additionally, Kendall's *T* coefficient were calculated to analyze the correlation between the usage frequency of different activity types. Only one significant result was found, which indicated that teachers who used more teacher demonstrations applied more practical activities, too, as Table 5 shows.

No significant correlation was found between the number of years of teaching or chemistry teaching experience and the frequency with which practical activities, demonstrations or video experiments are used in teaching or the proportion of experiments related to GSC (see Table 6). There was also no significant difference

Table 4: Results of Mann-Whitney U test.

	Not enough time in class	Not enough time outside of class to prepare	Lack of class time in a school laboratory
Frequency of practical activities	U = 1,126, p < 0.001	U = 988, p = 0.762	U = 1,450, p = 0.895
Frequency of teacher demonstrations	U = 1,685, p = 0.445	U = 929, p = 0.470	U = 1,440, p = 0.716
Frequency of video experiments	U = 1,788, p = 0.604	U = 1,007, p = 0.767	U = 1,386, p = 0.395

Table 5: Correlation between the usage frequency of different activity types.

	Kendall's T coefficient
Frequency of practical activities and teacher demonstrations	0.389, p < 0.001
Frequency of practical activities and video experiments	−0.110, p = 0.141
Frequency of teacher demonstrations and video experiments	−0.034, p = 0.651

Table 6: Correlation between teaching experience and usage of different types of activities based on Kendall's T coefficient.

	Teaching experience	Chemistry teaching experience
Frequency of practical activities	T = −0.031, p = 0.686	T = 0.015, p = 0.841
Frequency of teacher demonstrations	T = −0.089, p = 0.247	T = −0.080, p = 0.289
Frequency of video experiments	T = 0.031, p = 0.683	T = 0.046, p = 0.530
Proportion of GSC related experiments	T = 0.009, p = 0.904	T = −0.010, p = 0.892

Table 7: Differences in usage frequency among various activities according to level of degree.

	Mann-Whitney U test
Frequency of practical activities	U = 1,262, p = 0.209
Frequency of teacher demonstrations	U = 1,292, p = 0.282
Frequency of video experiments	U = 1,472, p = 0.720
Proportion of GSC related experiments	U = 1,075, p = 0.348

between the highest level of degree and the frequency of use of different activities (see Table 7). Teachers with a PhD were excluded due to the small sample size.

4.3 Open ended questions about usage of practical activities

The open-ended questions were analyzed simply, with responses that were identical or very similar being grouped into a single category. The categorization was carried out by two researchers, who then compared the resulting categories and corrected them in case of major differences, resulting in the following reliability coefficients ($k_{m,Q9}$ = 0.71, $k_{m,Q10}$ = 0.8, $k_{m,Q16}$ = 0.8), these values are above 0.6, so they are acceptable.[28,29] The following sections will focus on those categories that were not included in the quantitative questionnaire.

4.3.1 Aspects for the selection of practical activities

Hungarian teachers mentioned seven additional factors when asked what they consider when selecting practical activities. Several responses mentioned the use of everyday materials that are easily accessible, one teacher wrote "budget, easily available, everyday materials". Besides, the simplicity of practical activities was also common, a response was that experiments "should be easy to prepare". Some highlighted the aspect of making the experiment spectacular and motivating, while someone also wrote that it should be thought-provoking, as one respondent wrote practical activities should be "(…) thought-provoking, cause and effect chains should be deducible". Our respondents emphasized that students' individual properties, e.g. age and fields of their interest an important factor, too. One of the teachers wrote they consider "broadening students' fields of interest, presenting interesting facts, personal preferences of the students, if there are any".

Less common responses were the aspect of developing green skills, or choosing experiments required for graduation, or even choosing experiments that students could design themselves, in this way enhancing their creativity.

4.3.2 Other barriers to more frequent use of experiments

The most frequently mentioned factor was fear of accidents caused by students, although one teacher reported using household chemicals in his student experiments because their students could not follow the rules. In addition, overcrowded classes were also mentioned, and teachers who are beginners in chemistry (maximum 5 years of experience) also had concerns about experiments.

There was also a misconception among the responses, one teacher a teacher with 30 years of chemistry teaching experience and a bachelor degree described the lack of students' motivation for chemistry as a reason for not doing more practical activities, however Rogers and Fraser found that a demonstration every two weeks enhanced it.[30] Moreover, a paradox was found, this teacher claimed that chemistry is too theoretical for students, this is what prevents them from doing more practical activities.

4.3.3 Barriers and resources in relation to more frequent GSC practical activities

The most frequent responses are basically the same as those obtained in the quantitative survey. However, one answer related to the time issues pointed out that GSC practical activities are often longer than 45 min, so more flexibility in timetables may be needed, too.

Furthermore, several teachers wrote about the importance of self-development. Some said that a professional forum would be a great help, others mentioned the usefulness of a collection of GSC experiments. One teacher's response briefly summarizes some of the categories described above: 'vocational training, practical books, workbooks'.

4.3.4 Further comments on practical activities or GSC in chemistry education

On this question, the majority of teachers repeated what they had said before, so we will only focus on the few comments that contain novelty.

Some teachers underlined the importance and usefulness of this topic not only for environmental protection but also for chemistry education. Namely, practical activities can be proposed that require less chemicals, use everyday materials and are therefore inexpensive. In addition, it can help to engage students, as they can understand chemistry concepts while learning about how they can be "saviors of the planet", as one participant has written.

For this reason, one teacher suggested that the curriculum could be strengthened by reducing the number of numeracy tasks. Nevertheless, a counterargument was made that GSC is already so strongly represented in the curriculum that it is a barrier to learning basic chemical concepts in sufficient depth.

5 Discussion

5.1 Comparison with international data

The statistical analysis of the Hungarian results can be seen in a bigger picture compared to the snapshots presented at 16th ECRICE. [24]

According to teachers' responses, the global average frequency of student practical activities in chemistry lessons was once per month in September of 2024, while in Hungary the average responses indicate a slightly lower frequency, with a mode value of a few times per year. However, teacher demonstrations and experiments shown on videos are slightly more frequent. The proportion of teachers who chose the "never" option showed similar differences, with 6.3 % internationally and 11.8 % in Hungary in the case of student experiments, 6.1 % and 0.8 % respectively in the case of teacher demonstrations and 7.0 % and 2.3 % respectively in the case of video of chemical experiments.

The Hungarian data show a pattern parallel to European snapshots in terms of why chemistry teachers do not use more experiments in the classroom. The order of frequency of the factors was almost identical, with lack of time, laboratory equipment and curricular issues being the main factors marked, with the only difference being that in Europe, lack of confidence in handling chemicals was ranked last. Let us remember that these are the problems that have been identified in literature.

In Hungary, we found that teachers who identified lack of teaching time as the main barrier to practical activities used significantly fewer student experiments than those who did not consider this a barrier. At the same time, the number of practical activities showed a positive correlation with the number of teacher demonstrations, so we did not find what we expected before performing the calculations, namely that respondents replaced student experiments with teacher demonstrations due to lack of time. Nevertheless, we still believe that time is the key factor behind the phenomenon that teacher demonstrations are more common than practical activities.

It is also worth pondering the teacher's comment on the use of household materials to avoid accidents during student experiments. This parallels the intents of green chemistry to use less hazardous chemicals. Experiments

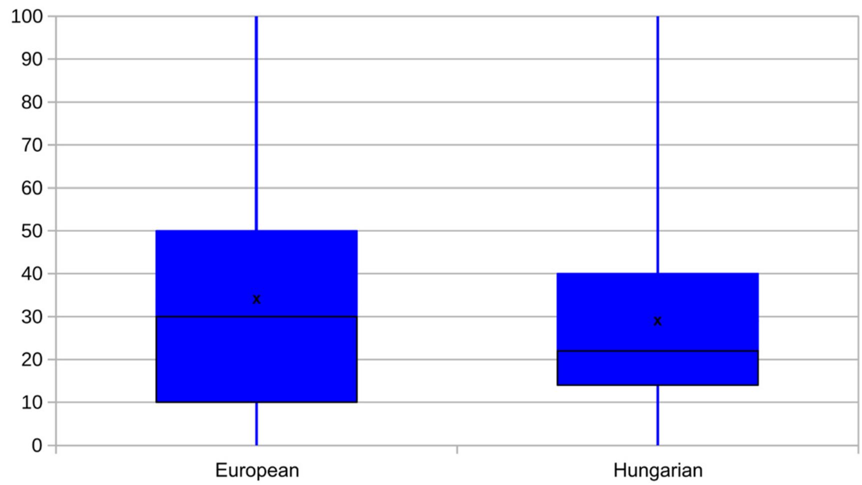

Figure 2: Comparison of the percentage of experiments related to GSC.

in the field of green chemistry can also help teachers who fear possible accidents to use more practical activities in their work.

Figure 2 shows that Hungarian respondents use a lower proportion of GSC experiments than the European average ($mean_{EU}$ = 34, $mean_{HU}$ = 29, med_{EU} = 30, med_{HU} = 22), but the quartile is smaller than the European range (int_{EU} = 10–50, int_{HU} = 14–40), so the sample was more homogeneous. There was only one notable difference between the Hungarian and European scores on the choice criteria of the GSC experiments, with an average of 3.6 for the importance of local issues in Europe, compared to 3.1 in Hungary. Therefore, an important question for further research is whether the fact that Hungarian chemistry teachers have rated local environmental issues as less important in their choice of GSC activities is not a reason for the fact that they use fewer experiments of this kind in their work.

At the same time, the homogeneity of the Hungarian responses also meant that statistical tests did not reveal any significant differences between groups with different levels of experience. This might suggest that more experienced teachers also trained themselves in the field of GSC, as younger teachers studied these topics at university.

5.2 Limitation

Around 5 % of chemistry teachers in Hungary responded to the questionnaire, which is a good ratio. However, convenience sampling was used, so the sample cannot be considered representative, which limits our results. Furthermore, the population pyramid is top-heavy, which may explain why no statistical calculations have led to significant results.

6 Conclusions

As teacher trainers, we have some tasks to do in relation to the difficulties of the novice teachers and the experienced teachers' desire for self-development. We need to help novice teachers to increase their confidence to use more practical activities in their work, as the most common response for open ended questions was related to fear of accidents and being a novice in teaching chemistry. In the context of this project, it is worth mentioning that green chemistry experiments can also address these worries, as it aims to use less hazardous chemicals.

We should also organize professional forums and training courses for more experienced teachers, who responded that this would be of great help to them. They also mentioned the usefulness of a collection of experiments, which is one of the aims of this IUPAC project.

Besides, some of our participants have not seen the usefulness of practical activities in the field of motivation. However, the literature says even one teacher's demonstration every two weeks has significant impact, but some of our respondents disbelieve, thus we should educate them and somehow show them the power of practical activities.

Finally, attitude-formation work is also needed, as respondents in Hungary did not consider linking experiments to a local environmental issue as important as the European average, although the snapshot data from Asia suggests that such experiments can better engage students, as Asian teachers responded that it is important to consider local issues when choosing GSC activities, and that such kind of activities are motivating for students.[24] The opportunity to work with in-service teachers and to create a professional forum is provided by our regular summer in-service teacher training, which we plan to enhance based on these results.

Acknowledgments: We would like to thank the project leaders of the IUPAC Teacher Survey on Practical Activities and the organizers of ECRICE 2024 for allowing us to participate in this research.
Research ethics: This study received Eszterházy Károly Catholic University ethics approval (reference number: RK/771/2025).
Informed consent: Informed consent was obtained from all individuals included in this study.
Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.
Use of Large Language Models, AI and Machine Learning Tools: When writing the abstract, the Le Chat model was used to summarize the chapters.
Conflict of interest: The author states no conflict of interest.
Research funding: Funding for this project was provided by the International Union of Pure and Applied Chemistry (https://iupac.org/project/2023-002-2-050/). Additional internal research funding to support this project has been provided by the project leader's institution, Deakin University. The funding organizations played no role in the study design; in the collection, analysis and interpretation of data; in the writing of the article; or on the decision to submit the article for publication.
Data availability: Selected anonymized data and summary descriptions will be available on the project website (https://eschemistry.org/iupacsurvey/). (Not necessarily from Hungary).

References

1. Delaney, S.; Chiavaroli, L.; Dissanayake, T.; Pham, L.; Schultz, M. International Teacher Survey on Green and Sustainable Chemistry (GSC) Practical Activities: Design and Implementation. *Chem. Teach. Int.* **2024**, *6* (3), 295–309.
2. Seery, M. K. Establishing the Laboratory as the Place to Learn How to Do Chemistry. *J. Chem. Educ.* **2020**, *97* (6), 1511–1514.
3. Hawkes, S. J. Chemistry is Not a Laboratory Science. *J. Chem. Educ.* **2004**, *81* (9), 1257.
4. Windsor, S.; Bailey, J. Impact of Chemistry Experiments Outreach Program on Learning and Attitudes for Students in their Penultimate Year of Schooling. *Teach. Sci.* **2016**, *62* (1), 43–53.
5. Kousa, P.; Kavonius, R.; Aksela, M. Low-Achieving Students' Attitudes Towards Learning Chemistry and Chemistry Teaching Methods. *Chem. Educ. Res. Pract.* **2018**, *19* (2), 431–441.
6. Gericke, N.; Högström, P.; Wallin, J. A Systematic Review of Research on Laboratory Work in Secondary School. *Studies in Science Education* **2023**, *59* (2), 245–285.
7. Hofstein, A. The Laboratory in Chemistry Education: Thirty Years of Experience with Developments, Implementation, and Research. *Chem. Educ. Res. Pract.* **2004**, *5* (3), 247–264.
8. Rusek, M.; Chroustová, K.; Bílek, M.; Skřehot, P. A.; Hon, Z. Conditions for Experimental Activities at Elementary and High Schools from Chemistry Teachers' Point of View. *Chem.-Didact.-Ecol.-Metrol.* **2020**, *25* (1–2), 93–100.
9. Zengele, A. G.; Alemayehu, B. The Status of Secondary School Science Laboratory Activities for Quality Education in Case of Wolaita Zone, Southern Ethiopia. *J. Educ. Pract.* **2016**, *7* (31), 1–11.
10. Horváth, I. T. Zöld Kémia. *Magyar Tudomány: Kémia* **2002**, *CVIII.-Új folyam, XLVII* (12), 1585–1588.
11. Anastas, P. T.; Warner, J. C. *Green Chemistry: Theory and Practice*. 1. paperback; Oxford University Press: Oxford, 2000.

12. United Nations Secretary-General; World Commission on Environment. Report of the World Commission on Environment and Development: Note by the Secretary-General; A/42/427; United Nations: New York, 1987; p 374. https://digitallibrary.un.org/record/139811?ln=en&v=pdf (accessed 2025-05-21).
13. Horváth, I. T. Introduction: Sustainable Chemistry. *Chem. Rev.* **2018**, *118* (2), 369–371.
14. United Nations Transforming our World: The 2030 Agenda for Sustainable Development. Resolution Adopted by the General Assembly on 25 September; A/RES/70/1; United Nations: New York, 2015; p 35. https://sdgs.un.org/2030agenda (accessed 05 21, 2025).
15. Mika, J. Education in the Sustainability Development Goals (2016-2030), Sustainability in the Education. *J. Appl. Tech. Educ. Sci.* **2017**, *7* (4). eISSN 25605429 https://doi.org/10.24368/JATES.V7I4.10.
16. United Nations Environment Programme *Specialized Manual on Green and Sustainable Chemistry Education and Learning*; Advancing Green and Sustainable Chemistry Education and Learning in All Segments of Society: Geneva, 2023.
17. Apotheker, J. Introduction to the Special Issue on Green Chemistry. *Chem. Teach. Int.* **2022**, *4* (2), 117–119.
18. Korm. rendelet a Nemzeti alaptanterv kiadásáról (1995); X.26; Vol. 91., pp 5306–5547.
19. Korm. rendelet a Nemzeti alaptanterv kiadásáról, bevezetéséről és alkalmazásáról (2012); VI.4; Vol. 66., pp 10635–10847.
20. Korm. rendelet a Nemzeti alaptanterv kiadásáról, bevezetéséről és alkalmazásáról szóló 110/2012. (VI. 4.) Korm. rendelet módosításáról (2020); I.31.; Vol. 17., pp 290–446.
21. Hivatal, O. *Útmutató a Pedagógusok Minősítési Rendszerében a Pedagógus I. és Pedagógus II. fokozatba Lépéshez, 6th, Modified ed*, 2019.
22. EMMI rendelet a tanári felkészítés közös követelményeiről és az egyes tanárszakok képzési és kimeneti követelményeiről; I.30.; Vol. 15., pp 979–1324.
23. Abrahams, I.; Millar, R. Does Practical Work Really Work? A Study of the Effectiveness of Practical Work as a Teaching and Learning Method in School Science. *Int. J. Sci. Educ.* **2008**, *30* (14), 1945–1969.
24. Delaney, S.; Devetak, I.; Stojanovska, M.; Rodic, D.; Schultz, M. Snapshot of IUPAC Teacher Survey on Green and Sustainable Chemistry Practical Activities – European and Global Perspectives. In *Presented at 16th European Conference on Research in Chemical Education (ECRICE)*, Lisbon, Portugal, 2024.
25. Lente, G. Statisztikai Adatok a Kémiaoktatás Helyzetéről. *Magy. Kem. Lapja* **2024**, *LXXIX* (6), 170–171.
26. The Jamovi Project *Jamovi*, 2024. https://www.jamovi.org.
27. R Core Team *R: A Language and Environment for Statistical Computing*, 2024. https://cran.r-project.org.
28. Sántha, K. Numerikus Problémák a Kvalitatív Megbízhatósági Mutatók Meghatározásánál. *Iskolakultúra* **2012**, *22* (3), 64–73.
29. Dafinoiu, I.; Lungu, O. *Research Methods in the Social Sciences/Metode de Cercetare În Ştiin,Tele Soziale*; European Social Inclusion; Lang: Frankfurt am Main Berlin Bern Wien, 2003.
30. Rogers, J. R.; Fraser, B. J. Sex and Frequency of Practical Work as Determinants of Middle-School Science Students' Learning Environment Perceptions and Attitudes. *Learn. Environ. Res.* **2023**, *26* (2), 315–336.