CONTEXT-BASED STUDENT RESEARCH PROJECT WORK WITHIN THE FRAMEWORK OF THE ANALYTICAL CHEMISTRY COURSE

N. Stozhko, B. Bortnik, A. Tchernysheva, E. Podshivalova
Ural State University of Economics (Russia)

Abstract. The paper discusses student research project work as an essential component of the context-based approach to teaching analytical chemistry. The key principles of student research project work were formulated. Step-by-step planning and organization of this work was proposed considering different functions of the teacher and the student in the research project activity. The context-based approach was illustrated by an interdisciplinary project on designing software for measuring nitrates in vegetables. The effectiveness of the research project work was evaluated by a students' survey. Attitudes toward research projects were very positive and students developed a better understanding of practical importance of analytical chemistry.

Keywords: student research project; interdisciplinary project learning; context-based learning; software resource for analytical chemistry

Introduction

Student research project work (SRPW) is an essential component of higher education innovative teaching and learning. Students benefit from research exercises by acquiring and developing a range of essential inquiry-based skills such as search of relevant information and design of a research task. They learn advanced research technologies and instrumentation; master measurement skills and statistical processing of obtained results; develop analytical thinking and ability to draw conclusions and make recommendations. Due to this, students gain the essential competences required for their professional careers. SRPW is a compulsory component of university degree programs all over the world, though forms of its implementation may vary due to differences in educational settings and levels.

In the Russian tertiary sector, SRPW is introduced in the curriculum as a mandatory form of student academic performance, such as a coursework and a final degree project. In addition, some universities have initiated the establishment of the so called 'student research societies' and development laboratories, which coordinate student research work; organize scientific conferences and contests of students' research works; publish students' papers etc. For the last decade, many Russian universities, similar to their international colleagues, have introduced project-based learning. Project-based learning (PBL) is a popular model that organizes learning around projects: a research project has become not only a tool of student assessment or their self-realization (as it was before), but also as a learning process. The benefits of PBL have gained particular importance with the introduction of the competence-based approach to higher education.

In the present context of lower interest in science-related education among students worldwide, their apathy and passivity towards the learning process (Akinbo, 2014; Gordeeva, 2014; Gendjova, 2017), PBL, based on innovative approaches and, at the same time, "on the principles of coherence, consistency and tradition" (Toshev, 2017) involves students in design, problem-solving, decision making, or investigative activities; facilitates a greater degree of student independence; and culminates in realistic products or presentations; and eventually enhances efficacy of learning (Gendjova & Yordanova, 2009; Koch et al., 2017; Hastie et al., 2017). There are different strategies for employing PBL. The projects may be preformed individually or in groups of students, on specific topics or on cycles of interrelated topics. The cycles consist of multiple learning circles that include PBL and are spirally repeated to master the fundamental knowledge and skills (Ito et al., 2015).

PBL holds a highly regarded position in the modern educational paradigm as it reflects intensive integrative processes in science and education (Toshev, 2015; Hutchison, 2016). There are many possibilities for using PBL in teaching chemistry (King, 2012; Luis et al., 2013; Silva & Hambre, 2015; Tanaka, 2014), as well as in teaching interdisciplinary subjects (Cutright et al., 2014; Hutchison, 2016), including the projects that integrated courses on life-cycle nutrition, developmental psychology and functional foods (Lapp & Caldwell, 2012; Zhu & Fang, 2015).

In connection with the above mentioned, the aim of this paper is to develop a concept of SRPW that will be able to fully exploit the opportunities of PBL as part of the modern educational paradigm and competence approach. The objectives of the work are as follows: (i) to consider the principles that underlie the interaction between the teacher and the student during the project work; (ii) to consider the selection criteria for research topics for context-based projects in chemistry.

Methods

The Ural State University of Economics (USUE) (Yekaterinburg, Russia) and the Department of Physics and Chemistry served as the environment for organizing context-base student research. USUE offers bachelor's and master's degree programs in Commodity Management and Expertise, Food Processing Technologies and Public Catering, Biotechnology and other specialist areas. The curricula include several chemistry courses, one of which is analytical chemistry. This course is taught with the use of innovative teaching methods and techniques, among which interdisciplinary PBL holds a prominent position. Interdisciplinary PBL is the key element of planning and running SRPW in the Department of Physics and Chemistry (Stozhko et al., 2015). A special application of this teaching method in our study was determined by collaboration: students specializing in the study of two different subject areas – information technology and analytical chemistry – closely cooperated at each stage of the project development. The efficacy of SRPW was measured by students' questionnaires and by the outcomes of the student research project contests where students submitted their research works.

Results

The modern educational paradigm of teaching and learning provides for a substantial shift of the epicenter of the educational process from teacher-centered to student-centered pedagogy. During the transition from traditional to inquiry-based activities in the chemistry class, teachers can begin to adopt more facilitative roles (Corriveau et al, 2009). They guide student with questions to lead them towards developing a response or solution of their own rather than to be the sole source of knowledge when students fully relying on the teacher for solving problems occurring during the learning process. This change calls for establishing a different type of relationships between the teacher and the student at all stages of the educational process; they become equal partners. This is particularly evident in the organization of SRPW that demands student's independence and freedom in order to realize their creative potential.

Our experience has allowed formulating the following principles that underlie context-based SRP as a form of the teacher- student partnership: (i) innovative approach to solving a variety of tasks (scientific, practical, technological, pedagogical) and to offering ways of their completion; (ii) both parties' commitment and contribution to the research process and mutual complementarity; (iii) focus on the practical relevance of the research, a clear vision of its applied perspectives; (iv) students are pro-active at all stages of the research; (v) teachers create conditions for student self-actualization; (vi) both parties' interest in the successful implementation of the research.

In this partnership, each party – the teacher and the student – plays their own role. The key student and teacher activities at each stage of the project are given in Table 1.

Table 1. Key student and teacher activities in SRPW

Project stage	Teacher roles	Student roles
1. Identification of research area	– being aware of the most topical research issues related to a particular subject area; – working out recommendations for student project work. In case of contract research: introduction to the research problem.	– searching for topical issues, – relating the issues to the teacher recommendations; – determining the research avenue. In case of contract research: search for information related to the stated research problem; making decision on acceptance or rejection of the contract. Decision agreed with the teacher.
2. Setting of aims and objectives	– discussing the research problem, aims and objectives with the student	– analyzing the research problem; – reviewing the literature; – formulating the project aim, setting objectives, and posing hypotheses
3. Outline of study	– assessing the scope of the research; – estimating the time frame of the research and relate it to the framework of the educational process; – refining the outline of study.	– working out an outline of study in accordance with the estimated workload and the framework of the educational process; – agreeing on the outline with the teacher.
4. Selection of research methods and instrumentation	– guaranteeing students' access to laboratory facilities; – negotiating possible use of additional laboratory facilities for the best completion of the tasks.	– developing relevant methods and techniques – learning how to work with the equipment – justifying the use of additional laboratory facilities.
5. Experiment	– monitoring the experiment; – refining the experimental procedures (if necessary).	– preparing materials and instrumentation for the experiment; – running the experiment; – informing the teacher about the received data; – adjusting and modifying (if necessary) the experiment in agreement with the teacher.
6. Analysis of experiment results	– monitoring data processing; – discussing the results of the experiment; – evaluating the quality of student's experimental and theoretical work.	– processing statistical results; – analyzing the findings and evaluating their reliability; – presenting the results of the experiment graphically; – modeling the studied process; – agreeing on the obtained data with the teacher.

7. Conclusions and recommen-dations	– evaluating student's conclusions and recommendations; – making suggestions for refining conclusions and recommendations; – assisting in successful implementation of this stage and the project (if necessary).	– understanding the results of the experiment and their impact; – making conclusions and recommendations; – agreeing on the conclusions and recommendations with the teacher.
8. Evaluation	– identifying criteria for the project evaluation; – arranging the presentation and evaluation of the project .	– selecting strategies to present findings (presentation, report, article, etc.); – agreeing on the form of the data presentation with the teacher; – preparing a presentation of the project; – presenting and defending findings .
9. Promotion	– exploring possibilities of promoting the project; – selecting strategies to promote the project; – resolving the copyright issues; – coordinating all this with the student.	– proposing strategies to promote the project – promoting the project.

The effect of applying the above mentioned principles and performing key activities within the established relationships between the student and the teacher is exemplified below.

The research project 'Designing a software resource for analyzing nitrate ions in vegetables' was developed to improve the measurement of nitrates in vegetables in order to assess the safety of these products. The project objectives are innovative in terms of application: to offer a rapid test and enhance the quality of chemical analyses; in terms of technology: to ensure the automation of tests; in terms of pedagogy: to apply the context-based approach to developing key professional competencies. The project was carried out by two undergraduate students with different majors: one student's major was Mathematical Software and Information Systems Administration (hereafter ='Programmer"), the other's – Biotechnology (hereinafter 'Analyst'). The guidance of the project was provided by a teacher of the Department of Chemistry. The Programmer was responsible for the IT content of the project, while the Analyst dealt with chemical analysis aspects related to the issue of food safety. The practical and professional foci of the project were stated in its goals and objectives tailored to the priority objectives of the food industry sectors: to provide the population with healthy and safe food products. The roles and functions of the teacher and the student complemented each other (see Table 1). The Analyst and the teacher selected a research problem, set research objectives and determined the methods of analysis. Then the Analyst worked on the technical specification for the Programmer's work that was reviewed by the teacher. The research group had regular meetings, which helped the Programmer and the Analyst clearly understood the stages of the project, while the teacher was able to monitor the working process.

In the course of the project work, a software resource was designed, comprised of two modules: (1) Solutions and (2) NO_3-ISE. The modules were designed to measure the concentration of nitrate ions by using the method of ionometry with a nitrate-specific electrode and to assess the accuracy of the results. The Solutions Module was used to determine the activity of ions in the solution of strong electrolytes, which impacted the rate of chemical reactions occurring in the solution. The Solutions Module offered calculations of the ionic strength of the solution, the activity coefficients and the activity of cations and anions present in the solution. The activity of the ions directly affected the analytical signal registered by the nitrate-specific electrode which was used in the NO_3-ISE Module. To obtain an analytic signal, the analyzed sample was prepared by removing nitrate ions using 1% alum solution. The sample preparation stage was followed by measuring the redox potential of the analyzed solution with the nitrate-specific electrode and calculating the amount of nitrate ions in the sample with regression analysis (Ordinary Least Squares, OLS). The obtained results were compared with maximum permissible concentrations (MPC) of nitrates in products. The original software resources guaranteed express analysis.

The practical part of the project focused on analyzing samples of local (cabbage, beetroots, carrots) and imported (tomatoes) vegetables, purchased in the supermarkets of Yekaterinburg. The results of the analysis are presented in Table 2.

Table 2. Concentration and MPC of nitrates in vegetables, obtained with the ionometric method

Type of vegetables	Nitrate-ion concentration, mg/kg	MPC (mg/kg)
Beetroot	1310±30	1400
Tomato	139±5	150
Carrot	126±7	250
Cabbage	305±14	500

Using the received data, students draw conclusions about the quality of the products and their suitability for use. They also assessed if the developed software resource was feasible for this analysis, and made some recommendations. The teacher evaluated the conclusions and refined them if necessary. Later, at the stage of the project presentation, students developed presentation materials which were discussed at the seminars and considered for submission to contests and competitions. The last stage - the promotion of the project – was teacher-led, as it was the teacher who dealt with the issues related to copyright, awards and certificates.

In recent years, the issues of quality assurance and student evaluation of teaching and learning environment have generated considerable interest (Tomova et al., 2014; Stozhko, 2016). To find out what students think about SRPW, a multiple-choice questionnaire was designed. The sample size was composed of 14 students who worked on different research projects under the guidance of five teachers. All ethical aspects of the survey were agreed upon and observed. The results of the survey are illustrated in Table 3.

Table 3. Student evaluation of SRPW

1. To what degree did SRPW meet your expectations?	**Number of responses**
– Above my expectations	9
– Along with my expectations	3
– Below my expectations	-
– I don't know	2
2. How did your interest in analytical chemistry change?	
– It increased significantly.	5
– It increased.	7
– It didn't change.	1
– I don't know.	1
3. How did your perception of the importance of analytical chemistry change?	
– I understand it better; I learnt new applications of chemistry in real life	9
– My perception didn't change.	5
– My earlier perception was broader. I thought that analytical chemistry is more important.	-
– I don't know.	-
4. How do you describe the teacher role during the joint project work?	
– The teacher gave me a free hand, provided me with some assistance and evaluated the results.	1
– The teacher gave me a free hand and provided me with substantial assistance.	8
– The teacher was in a complete control of my work, told me what should be done at each stage of the project.	4
– The teacher did most of the work.	1
– I don't know.	-

5. How do you assess SRPW organization?	
– Excellent.	10
– Satisfactory	3
– Unsatisfactory.	-
– I don't know.	1

The responses presented in Table 3 show that the majority of the students highly assessed the organization of SRPW: their expectations were met and even exceeded; the students got more interested in analytical chemistry; they understood how the discipline could be applied in their professional life. The students perceived their learning and teacher's activity more critically. Students' participation in contests could also add to effectiveness of SRPW. For example, the described project received an approval of the panel at the 2017 Food Safety International Competition of Young Researcher Projects, held in Yekaterinburg ('Nutrition as a Key Factor of Human Health' Category). Among the nominees were two other research projects: 'Automated Potentiometric Determination of Two Protolytes Used for Hydraulic Fracturing of Oil-Bearing Strata', and 'Electrochemical Evaluation of Antioxidant Properties of Ural Wild Plants'.

Conclusion

Student research project work (SRPW) is a critical component of the university science education. Its most visible effect is in students' enhanced research creativity and innovative potential as professionals. Taking into account the competence-based approach underlying the contemporary higher education, while planning and organizing SRPW in applied sciences, and analytical chemistry in particular, it is advisable to promote context-based research and studies. An approach to SRPW proposed in the paper is based on the principles and functions that the teacher and the student perform while interacting during research. SRPW has positive effect on attaining learning objectives. An example of a context-based research project in analytical chemistry, presented in this article, includes the design and application of a software resource allowing to measure nitrates in vegetables. Students' responses to the questionnaire showed that the students positively view SRPW. Recognition of the projects presented at research contests and competitions is another token of SRPW efficacy. We believed that our experience can be shared by many educational institutions.

REFERENCES

Akinbo, O.T. (2014). Bottled water analysis: a tool for service-learning and project-based learning (pp. 149 – 191). In: Roberts-Kirchhoff, E.S., Mio, M.J. & Benvenuto, M.A. (Eds.). *Service learning and environmental chemistry: relevant connections.* Washington: American Chemical Society.

Corriveau, L., Boyer, M. & Fernandez, N. (2009). La qualité en éducation: un enjeu de collaboration à cerner. *Innovation J., 14*(3), 1 – 23.

Cutright, T.J., Evans, E. & Brantner, J.S. (2014). Building an undergraduate STEM team using team-based learning leading to the production of a storyboard appropriate for elementary students. *J. Sci. Educ. & Tech.*, *23*, 344 – 354.

Gendjova, A. (2017). Students' attitudes related to science and scientists: stereotypes, peculiarities, implications. *Chemistry, 26*, 139 – 154 [In Bulgarian].

Gendjova, A. & Yordanova, B. (2009). Project-based learning in science at the American College of Sofia. *Chemistry, 18*, 255 – 267 [In Bulgarian].

Gordeeva, I.V. (2014). Sientism crisis as a result of disappointment in science. *Historical, philosophical, political and legal sciences, cultural studies and art history: questions of theory and practice. 47*(9 – 2), 48 – 50 [In Russian].

Hastie, P.A., Chen, S. & Guarino, A.J. (2017). Health-related fitness knowledge development through project-based learning. *J. Teach. Phys. Educ., 36*, 119 – 125.

Hutchison, M. (2016). The empathy project: using a project-based learning assignment to increase first-year college students' comfort with interdisciplinarity. *J. Problem-Based Learning, 10*(1), art. no. 9.

Ito, T., Shin, M., Miyazaki, K., Iwata, S. & Sentoku, E. (2015). The effects of spiral educational method through PBL: KIT project design program. *Proc. 43rd SEFI Annual Conference 2015 – Diversity in Engineering Education: An Opportunity to Face the New Trends of Engineering*, June 29 – July 2, Orleans; France, art. no. 54688.

King, D. (2012). New perspectives on context-based chemistry education: using a dialectical sociocultural approach to view teaching and learning. *Stud. Sci. Educ., 48*, 51 – 87.

Koch, F.D., Dirsch-Weigand, A., Awolin, M., Pinkelman, R.J. & Hampe, M.J. (2017). Motivating first-year university students by interdisciplinary study projects. *Eur. J. Eng. Educ., 42*, 17 – 31.

Lapp, J. & Caldwell, K.A. (2012). Using food ethnographies to promote systems thinking and intergenerational engagement among college undergraduates. *Food, Culture & Society, 15*, 491 – 509.

Luis, C.E.M., Mellado, R.C. & Díaz, B.A. (2013). PBL methodologies with embedded augmented reality in higher maritime education: augmented project definitions for chemistry practices. *Procedia Comp. Sci., 25,* 402 – 405.

Silva, A.G.L. & Hambre, M.M. (2015). Effects of instructional strategies and proficiency levels on students' achievement. *Adv. Sci. Lett., 21*, 2382 – 2386.

Stozhko D.K. (2016). The question of the nature of labour market in the system of higher education of contemporary Russia. *Bull. North Ossetian State Univ.,* No. 3, 188 – 192 [In Russian].

Stozhko, N, Bortnik, B., Mironova, L., Tchernysheva A. & Podshivalova, E. (2015). Interdisciplinary project-based learning: technology for improving student cognition. *Research in Learning Technology, 23*, art. no. 27577.

Tanaka, M. (2014). Research and education as both wheels. *Kobunshi, 1,* 29 – 30.

Tomova, R., Gateva, P., Hadjiolova, R., Sabit, Z., Slavova, M., Chergarova, G. & Simeonov, V. (2014). Multivariate statistical assessment of dreem - Bulgaria: student's perceptions of the learning environment in the Medical University in Sofia. *Chemistry, 23*, 697 – 713 [In Bulgarian].

Toshev, B.V. (2015). The post-normal science: features and new trends. *Chemistry, 24*, 329 – 339 {In Bulgarian].

Toshev, B.V. (2017). For successful education. *Chemistry, 26*, 7 – 16 [In Bulgarian].

Zhu, S. & Fang, D. (2015). Teaching reform of functional foods course based on project learning. *Adv. J. Food Sci. & Tech., 8*, 105 – 108.

✉ **Dr. N. Y. Stozhko, Prof. (corresponding author)**
Physics and Chemistry Department
Ural State University of Economics
62, 8 Marta St.
Yekaterinburg, 62014 Russia
E-mail: sny@usue.ru