Science Education International
33(2), 192-202
https://doi.org/10.33828/sei.v33.i2.7

ORIGINAL ARTICLE

Developing Prospective Science Teachers' Using of Chemical Knowledge with Flipped Learning Approach in the Context of Environmental Problems

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ABSTRACT

This study aimed to investigate the effect of the analytical chemistry laboratory (ACL) course, designed, and conducted according to the flipped learning approach (FL) on prospective science teachers' (PSTs) meaningful understanding and interpretation of knowledge in the context of the environment. Seventy-three second grade PSTs participated in this action research, and the interventions lasted for 13 weeks. The ACL course was reorganized by replacing the traditional laboratory approach with the FL approach that established the context with the environment. The data were obtained through a conceptual understanding test (CUT) which was developed by the researchers, which consisted of five open-ended questions. The CUT was used as a pre-test and post-test along with an interview form. Results showed that the reorganization of the traditional laboratory course in accordance with the nature of action research and its integration with the FL approach had a positive effect on the prospective teachers' learning and opinions about the course. Furthermore, it was determined that PSTs' interpretation ability related to environmental problems in the chemical dimension improved significantly. However, despite this increase, it was concluded that they could not reach a sufficient level in terms of producing solutions to environmental problems. Considering that the effectiveness of FL practices both teaching subjects and environmental problems in ACL course, it is thought to be beneficial to use this approach in another laboratory course.

KEY WORDS: Action research method; analytical chemistry laboratory; chemical knowledge skills; environmental problems; flipped learning

INTRODUCTION

Laboratory practices have the advantage of enabling students to observe theoretical knowledge in practice, realize conceptual learning, and gain first-hand experience. Thanks to these practices, learners who cannot make sense of knowledge or cannot make inferences about the importance of knowledge in daily life could participate in more meaningful learning processes which are an important role in the integration of science and daily life contexts (Hofstein and Lunetta, 2004; Muñoz-Campos et al., 2020; Rigano and Ritchie, 1994; and Whisnant, 1982). While laboratory courses are effective, there are criticisms as these courses are mostly carried out with traditional approaches. The main criticism of these practices is that students are individuals who apply the recipes in the cookbook one by one and this situation prevents the realization of meaningful learning (Hofstein, 1988). In this case, the students are not given the opportunity to use the knowledge, interpret, make inferences, or conduct scientific discussions for the experiments (Hart et al., 2000), and thus, their motivation and learning are affected negatively. Therefore, it is a necessity that the laboratory practices should be arranged in a way that gives the students the opportunity to relate the scientific content to daily life. In this context, it is important to structure the laboratory practices so as to present them to students by associating theoretical knowledge with life and the environment, to determine the appropriate teaching approaches to achieve this, and to reorganize the functioning of laboratory courses within these approaches in terms of achieving effective results. These deficiencies are also present in the analytical chemistry laboratory (ACL) course offered in the undergraduate program of Science Teacher Education in Turkey.

When the content and process of the ACL course are examined, there are two main problems reveal. The first is the knowledge that is given at a purely chemical level and that the experiments are carried out by following certain pre-determined stages (Candaş et al., 2016; Kılınç-Alpat et al., 2011). The second problem that arises in parallel is that the reflections of the knowledge acquired in these learning processes in daily life are not mentioned (Gilbert, 2006; Karacop, 2017; and Milner et al., 2011). The solutions of the problems mentioned should not be limited to the laboratory practice process but should also include the process of reaching the information instead of literal knowledge prepared like the previous ones.

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33(2), 192-202
https://doi.org/10.33828/sei.v33.i2.7

The use of student-centered approaches is seen as the basic condition for students to access and to benefit from the knowledge they gain (Alkan and Erdem, 2013 and Hibbard et al., 2016). Many studies in the literature suggest several approaches to increase prospective teachers' interest and motivation, and thereby positively affect their academic success, to overcome the limitations of the traditional approach adopted in laboratory practice (Alkan and Erdem, 2013; Bokosmaty et al., 2019; Hibbard et al., 2017; Karacop, 2017; Kılınç-Alpat et al., 2011; Milner et al., 2011; Wieman, 2015; Wilcox and Lewandowski, 2016; and Wong et al., 2013).

In the literature, one of the approaches that can be used for this purpose is the Flipped Learning (FL) approach, which, by changing the traditional process of answering experiment preparation questions, conducting the experiment according to the given steps and reaching the result (Rigano and Ritchie, 1994), makes contributions to the implementation of laboratory practices and to obtain effective results (Hamdan et al., 2013). The reduction or elimination of problems encountered in ACL practices will eliminate the shortcomings of traditional approaches, and in line with characteristic of FL approach will be possible using student-centered laboratory practices that enable the students to participate actively in the learning process physically and mentally and support the realization of conceptual learning (Davies et al., 2013; Hibbard et al., 2017; and Roehl et al., 2013). The FL approach, which advocates that the teaching process should be rearranged according to students' personal needs and their learning speed (Bergmann and Sams, 2012), is based on the principle that students come to the classroom environment by preparing for the topic and reinforcing it with collaborative practices. In the classroom designed of the FL approach, learners come to the classroom by examining the videos or materials prepared for the subject or doing research outside the school and, unlike many other approaches, they gain prior knowledge and awareness on the subject, although to a limited extent, rather than hearing the information from the teacher for the first time in the classroom. In this way, students who are responsible for their own learning can shape the process depending on their learning speed.

The model of the FL approach widely used in the classroom will not make teaching practices more interesting for higher education levels (e.g., prospective teachers), it can also negatively affect their ability to access and choose the right knowledge. The practices of FL approach can be arranged in a way that prospective science teachers (PSTs) will take responsibility for their own learning and information needed. In this context, organizing the FL approach to include accessing and needing knowledge for PSTs will increase their motivation and provide meaningful learning (Roehl et al., 2013). In the interviews with PSTs, the idea of conducting the ACL practices in the student-centered way and transforming laboratory into a form that supports their individual learning to overcome the difficulties experienced in the lesson was revealed (Candaş et al., 2016). The literature analysis shows that using of the FL approach in the chemistry education field has produced effective results (Bergmann and Sams, 2012; Bokosmaty et al., 2019; Davies et al., 2013; Fitzgerald and Li, 2015; Hibbard et al., 2016; Ryan and Reid, 2016; Schultz et al., 2014; Seery, 2015; Trogden, 2015; and Weaver and Sturtevant, 2015). Therefore, that using FL approach in the ACL courses will serve PSTs' individual learning and relationships between content and reflection of content in daily life.

As the second problem encountered in laboratory practices, the learned knowledge cannot be associated with daily life and that, therefore, the value of the knowledge cannot be realized by the learners (Gilbert, 2006; Karacop, 2017; and Milner et al., 2011). When students realize that knowledge gained in chemistry is the basis of facts and phenomena in their daily life, they can have the opportunity to make sense of their knowledge in real life situations and their motivation increase to the course (McCombs, 1996), and ultimately, conceptual learning occurs in this way (Gilbert, 2006; Koçak and Önen, 2012; and Wong et al., 2013). Otherwise, chemistry subjects are seen as abstract information that is not related to daily life for students (Childs et al., 2015; Danker, 2015; Koçak and Önen, 2012; and Yildirim et al., 2013). In studies conducted on this subject, it has been noted that students can solve problems operationally using the necessary formulas, but they cannot explain the underlying reasons for this problem, because they do not have sufficient conceptual depth (Ayas and Özmen, 1998; Balkan-Kıyıcı and Aydoğdu, 2011; Nakhleh and Mitchell, 1993; Niaz, 2005; Vos et al., 2010; and Yildirim et al., 2013). These problems were also experienced in the ACL course (Candaş et al., 2016). The practices carried out within the scope of the ACL course in the science teaching program comprises cation – anion analysis and gravimetric – volumetric analysis. Many of the chemicals used in these analyses are harmful pollutants for the environment from various sources (e.g., iron, lead, and mercury ions). In traditional laboratory practice, PSTs cannot go beyond learning how to detect the presence of these chemicals. Rather than determining the presence of these chemicals in the solutions, PSTs are expected to carry out activities related to the environments, in which these chemicals can be found, in which sources may be involved in these environments, knowledge about their effects on and damage to the environment and living organisms and producing alternative solutions to remove these chemicals from the environment. In this way, PSTs will be able to produce more realistic and scientific solutions as they will have the opportunity to acquire in-depth scientific knowledge. Considering the content and theoretical background of the experiments carried out in the ACL, the creating learning settings associated with the environment and environmental problems and the conducting experimental process in a sufficient relationship with daily life in the environmental context will contribute to the solution of the second problem. Thus, changing content of the practice will encourage PSTs in terms of fostering the ability to relate their knowledge to daily life and transferring this to their own students in their professional life. In this way, it is anticipated that PSTs will find

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answers to the question of "where and when they would use the acquired knowledge" and that they will have the opportunity to start the profession as environmentally conscious teachers.

Thus, both adoption of the FL approach and the opportunity to relate the practices carried out with environmental problems will not only make sense of knowledge but will also bring advantages such as interpretation, evaluation, and awareness of what can be done as an individual. In this way, environmental education courses in faculties of education would go beyond just giving knowledge about the environment (Pooley and O'Connor, 2000) and support PSTs in internalizing this knowledge and design teaching environments, in which they will use it in their profession. Besides enabling PSTs to approach the environment and environmental problems with sensitivity, the training, they will take in the fields directly related to the environment, such as chemistry and biology, is important for them to evaluate these problems within the framework of scientific knowledge and to educate students who will produce rational solutions. In this way, while the chemistry knowledge that forms the basis of laboratory practices is learned and used theoretically, the importance of this knowledge in the context of the environment will be noticed by the learners. At this point, adapting the knowledge to real-life contexts, especially in courses requiring in-depth theoretical knowledge and relatively high-level laboratory practices beyond general and superficial knowledge such as analytical chemistry, has significant role for sound conceptual understanding.

For these reasons, this study looked for an answer the question that what is the effect of the ACL course, designed, and conducted to the FL approach, on PSTs' understanding and interpretation of chemical knowledge within the scope of the environmental pollution?

Purpose Statement

This study investigated the effect of the ACL course, designed, and conducted according to the FL approach, on PSTs' meaningful understanding and interpretation of knowledge in the context of the environmental pollution. By means of the ACL course designed based on the FL approach, which goes beyond traditional approaches, learners would be responsible for their own learning and contribute to the realization of the process actively. Moreover, the opportunity to experience a different approach first-hand and the environmental education component would support the realization of meaningful learning. Learners would be able to approach the events and problems in their environment with a more scientific view and to find solutions by making more realistic evaluations in a scientific sense. Due to the nature of FL processes, it was anticipated that PSTs' research on environmental issues, recognizing and interpreting environmental problems outside learning environments, and thinking about these problems at a scientific level would have positive effects on both their approaches to the ACL and their participation in the process.

Although it was thought that a one-semester (13 weeks) implementation period was not sufficient in an educational study, in which new approaches were tested, searching of an appropriate approach to the content of the ACL and designing of the process involves a few years of research. By designing all data collection tools in accordance with the nature of qualitative data, an attempt was made to avoid this limitation by planning to provide more detailed information. The data analysis of study was formed by frame of students' conceptual understanding of association of content and environment and opinions about the new setting.

METHODOLOGY

The study was conducted in accordance with the requirements of the action research method. The researchers lectured the ACL course for 3 years with the traditional laboratory approach. However, in the feedback given by PSTs throughout the term and at the end of the term over 3 years, it was observed that they had problems about identifying areas, where they could use the knowledge that they learned in the course and associating it with daily life. The inability of conceptualization of knowledge learned negatively affected PSTs' interests and attitudes toward the course. This caused unintended consequences on both PSTs' learning desire in the teaching process and academic achievement. Researchers emphasized that this situation could be related to the traditional laboratory approach, which was the teaching method of the ACL course. Action research was chosen as the method of the study to solve these problems in the ACL course and to improve the quality of teaching and learning (Capobianco, 2007). The course instructors worked as teachers-researchers to solve these perceived problems, create changes in teaching and learning environment, and enable PSTs to achieve their learning outcomes. In action research, teachers integrate a scientific cycle that includes planning, action, and reflection into their normal processes. Accordingly, in this study, the researchers, with the contributions of an education expert in the field, identified the problem more clearly and exchanged ideas for its solution. First, the idea that the content of the ACL course is related to environmental problems was emphasized, based on the statements in the previous years that PSTs could not interpret the chemical knowledge in the context of daily life. To improve the efficiency and quality of the teaching process, it was decided to replace the traditional laboratory approach with an intentional content model from the FL approach. Considering the problems in ACL course, a research process was designed by enriching the content of the course and changing the teaching method. The flow chart of the action research used in the study is shown in Figure 1.

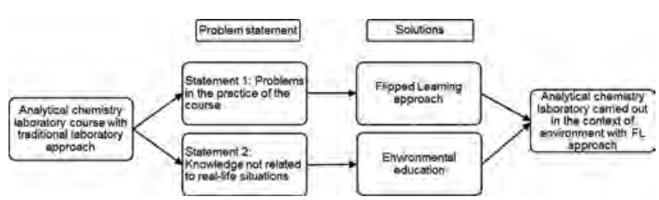

Figure 1: Flow chart of study

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Participants

The research was conducted with 73 second grade PSTs (61 female, 12 males, aged 19–21 years) with face-to-face training in the fall semester before the pandemic period. PSTs took General Chemistry I and II courses that theoretical and laboratory for both in the 1st year, and during the implementation process, they attended analytical chemistry theoretical and laboratory courses for 2 h a week. Before starting the research, the participants were informed about the teaching process and data collection tools, and their name would be kept hidden. It was stated to the participants that the part of participating in the research was completely voluntary and that they could leave the study at any time during the process.

Implementation Process

The content and way of implementation of the ACL course was rearranged line within the intentional content model from FL approach that suggested to have positive effect in learning (Bergmann and Sams, 2012). In the intentional content model, which enables active learning, sound understanding, peer teaching, problem-based learning by means of self-research, and knowledge acquisition by students (Kardaş and Yeşilyaprak, 2015), the subject of the content to be researched is given to the students by the teacher. In this way, students' independent learning, self-efficacy belief (Enfield, 2013), learning motivations (DeSantis et al., 2015), and self-regulation skills (Bajurny, 2014) are developed. PSTs should have these skills to achieve the objectives aimed at educating individuals as researchers in the science curriculum. Therefore, this model was chosen for creating active learning settings, where sound and meaningful learning takes place.

To increase communication in the ACL course, PSTs were divided into four groups and each group included 18–20 members. The groups attended 2 h of laboratory classes in each week for 13 weeks and worked in groups of 3–4 people during the teaching process. The lesson included discussion, problem solving, and conducting experiment steps (Table 1 for a sample lesson content).

Table 1: A summary of two FL weeks in ACL course

Weekly topic/key concepts to explore	ACL course
Week 8: An introduction gravimetric analysis Definition of gravimetric analysis, its purpose and in which areas it is used	• In large group discussion, PSTs construct common grounds that shows what gravimetric analysis is and what it is used for • PSTs conduct small group discussion on how to use gravimetric analysis in environmental context in line with common ideas reached at the beginning of the lesson
Week 9: Gravimetric analysis experimentation and environmental context Preparation for the experiment and its materials, and how gravimetric analysis can be used for environmental problems	• PSTs works collaboratively for selecting the appropriate materials to be used in the experiment and to reach the conclusion of the analyses and note their observations • PSTs discuss with large group whether it is possible to determine the presence of heavy metals by such a method • Finally, PSTs question what they can do as an individual and as a teacher toward the environment in the light of this knowledge

ACL: Analytical chemistry laboratory, FL: Flipped learning

Traditional laboratory approach includes well-structured experimental stages and theoretical process on rote learning has been transformed into a learning environment, where PSTs can take responsibility for their learning, learn actively, and discuss with their peers (see supplementary material). For each lesson, the content was formed on student-centered activities that involve PSTs to extend the knowledge that they explored before course. Researchers' questions were designed to lead PSTs in whole lesson process to conceptualize the knowledge and environmental pollution relation. Therefore, the researchers shifted their roles in ACL course from instructive to mentor for facilitating of learning.

Data Sources and Analysis

The conceptual understanding test (CUT) which consisted of five open-ended questions by related to environmental pollution was used as a pre-test and post-test for determining PSTs' chemical conceptual understandings. The CUT, developed by the researchers, was reviewed for content validity by an expert in general chemistry education who taught from 25 years at the same institution, where study conducted. The first three questions in the CUT (Appendix) were designed to measure PSTs' general knowledge about "environmental pollution, soil pollution, and water pollution." The fourth and the fifth questions were expected to examine and assess, respectively, soil pollution and water pollution, PSTs' opinions on the effects of the presence, and amount of chemicals in soil or water. The obtained data were analyzed with the descriptive analysis method. The themes of the analysis were determined in parallel with the concepts, on which the questions in the CUT were structured and PSTs' answers were classified under these themes (causes, results, and prevention). In the analysis process, new themes (misconception, general comments, and environment) were formed particularly for the fourth and fifth questions. The reliability value was calculated 94.7%.

At the end of the implementation process, employing the interview form, PSTs' opinions about the ACL course which rearranged according to the FL approach and environmental context were obtained. In the interview form, which was designed as open-ended and reviewed by the expert, PSTs were asked to write their opinions about the teaching process within the framework of the course and the relationship between the environment and the experiences gained in the laboratory. PSTs' answers were subjected to content analysis. As a result of analysis, "learning process, FL, and suggestions" categories were revealed. The analyses were carried out by two researchers and the reliability value was 91% (Miles and Huberman, 1994). The analysis has been examined by the expert in general chemistry education.

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FINDINGS

The five open-ended questions asked to PSTs were handled one by one and the obtained data are presented.

PSTs' Chemical Conceptual Understanding by Related to Environmental Pollution

The findings obtained from PSTs' answers to the question (Question 1, Appendix) on environmental pollution in the CUT are presented in Figure 2.

Figure 2 demonstrated PSTs mostly focused on causes and results of pollution. Three categories (chemical pollution, urban pollution, and living beings) emerged under the causes theme and PSTs had some common ideas in this theme such as "chemical waste," "waste products," and "human" both in the pre- and post-test. On the other hand, even at lower frequencies more logical and scientific answers about the causes of pollution revealed after implementation. For example, "heavy metals" code manifested only in post-test even if not present in the pre-test. The frequencies under the results theme increased significantly in the post-test due to responses consequences on pollution.

PSTs' Chemical conceptual understanding by related to water pollution

The findings obtained from the question of water pollution and its sources (Question 2, Appendix) are shown in Figure 3.

In line with the answers to the second question, three themes appeared (causes, results, and environment). Some codes in both the pre-test and post-test were stated by the PSTs as a common opinion (e.g., factory waste, chemical waste, human, waste products, and damaging to living beings). On the other hand, when comparing the pre- and post-test results, the frequencies of certain codes (e.g., heavy metals, vessel waste, disturbs natural balance, and sea) increased significantly in the posttest. On the contrary to this situation, although some codes (e.g., trash, artificial substances, misuse of water, and so on) were expressed in the pre-test, these codes were not mentioned in the post-test.

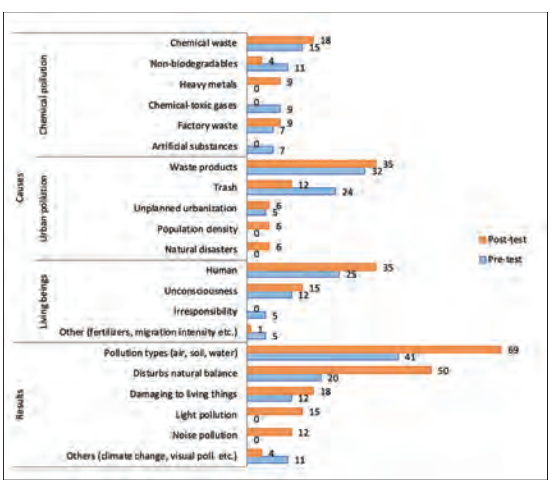

Figure 2: PSTs understandings on environmental pollution

PSTs' Chemical Conceptual Understanding by Related to Soil Pollution

The findings obtained from the answers to question of soil pollution and its sources (Question 3, Appendix) are presented in Figure 4.

Referring to the findings from the third question, PSTs' answers were collected under certain common codes on causes theme in both the pre- and post-test (chemical waste and agricultural activities in the chemical waste category, waste products in the urban waste category, and human in the living being's category). Meanwhile, only one code appeared as s common code in the results theme. Although there were fewer frequencies for the "heavy metals," "acid rain," "factory waste," and "trash" codes and there were no references to "mining activities" in the pre-test, the frequencies of these codes increased significantly in the post-test. While more codes with fewer frequencies were revealed in the pre-test, PSTs' opinions were collected under certain codes after the teaching intervention.

PSTs' Chemical Conceptual Understanding by Related to Diagnose Pollutants of Soil

In the fourth question (Appendix), PSTs were expected to explain which ions in the soil sample containing various ions which were pollutants and their reasons of answers. Figures 5 and 6 show the PSTs' understandings about the effects of the presence and amount of chemicals in soil.

As shown in Figure 5, PSTs stated that the chemicals that polluted the soil sample were cadmium, silicon, silver, boron, and iron, respectively. Mentions of other chemicals were below 20% in both the pre- and post-test. While the frequencies of cadmium and iron increased, after teaching process the other chemicals was expressed less than pre-test. When Figure 6 is examined, it is seen that PSTs' understandings about soil pollution were classified under the results, general comments, and misconceptions categories.

In Figure 6, the codes revealed in the pre-test were usually with superficial answers which frequency were low (e.g., it is metal, which decreases agricultural activities). After teaching implementation, common opinions appeared and that the most PSTs in the post-test expressed the "heavy metals" codes that were not revealed in the pre-test. Comparing the pre- and post-test findings, frequencies of some codes (harmful/toxic and damaging to soil) increased in the post-test. The frequencies of PSTs' answers were more intense in the results theme in both pre- and post-tests compared to other themes which are represented in Figure 6 (harmful/toxic, damaging to soil, and damaging to living beings), and also, in pre-test PSTs had various misconceptions, although a small number.

PSTs' Chemical Conceptual Understanding by Related to Diagnose Pollutants of Water

In the fifth question (Appendix), PSTs were asked to explain which ions in the water sample containing various ions pollute the water and why they thought this way. The findings obtained

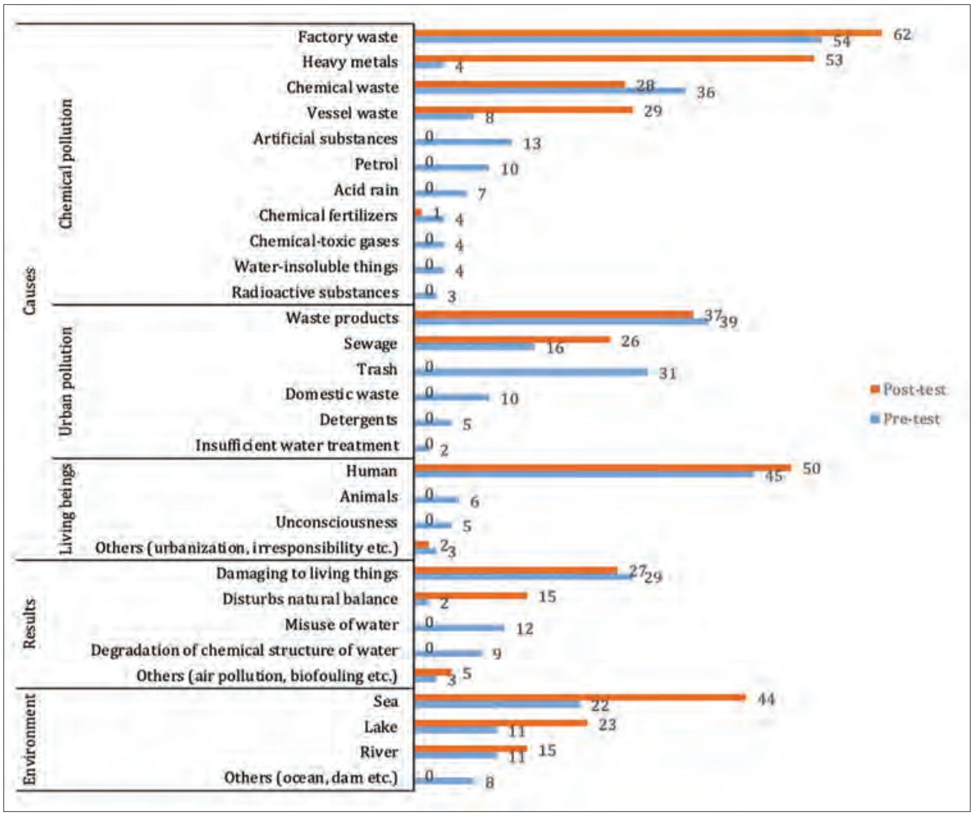

Figure 3: Prospective science teachers understandings on water pollution

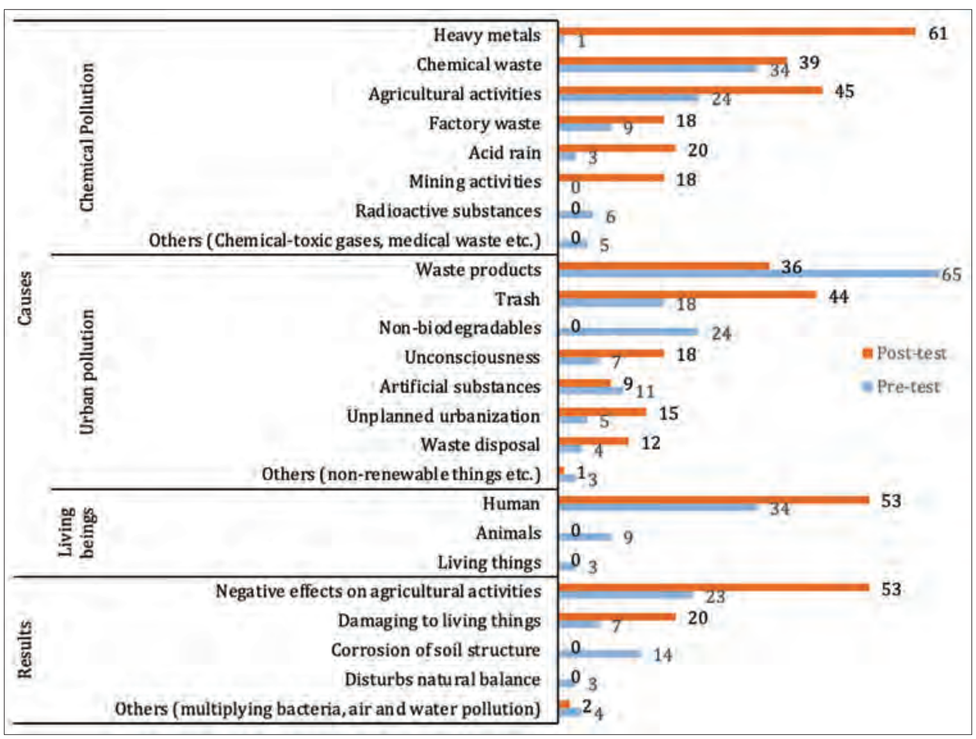

Figure 4: Prospective science teachers understandings on soil pollution

from PSTs' answers to the question about the effects of the presence and amount of chemicals in water are shown in Figures 7 and 8.

PSTs reported that the chemicals which had pollutant effects in the water sample were mercury, ammonia, lead, manganese, copper, sulfate, and phosphate, respectively (Figure 7). Comparing the

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pre- and post-test data, a decrease was observed in the frequencies for mercury, ammonia, and copper, while an increase was observed for lead and phosphate. Sodium, magnesium, oxygen, and chloride were expressed as pollutants at below 20%.

PSTs' answers on water pollution were classified under the themes of results, causes, general comments, and misconceptions. While PSTs' answers about water pollution were generally gathered under the results theme, the codes for the causes of water pollution were limited in both the pre- and the post-test. Considering the frequencies obtained in the post-test, "damaging to living things" and "pollutes the environment" codes in higher frequencies in PSTs' explanations were revealed. When pre- and post-test data were compared, the frequencies of the "heavy metals" code in general comments theme increased in the post-test significantly. In addition, although some PSTs had misconceptions about the chemicals in pre-test, statements in post-test does not include does not include any misunderstandings.

PSTs' Opinions on the ACL Course Conducted with FL

One week after completing the implementation of the ACL, PSTs reported their opinions on the practices performed during the semester. PSTs' opinions about the practices were gathered under the categories of "teaching process," "FL" and "suggestions." The opinions in the "teaching process" and "FL" categories were classified as positive and negative opinions, whereas most PSTs had positive opinions about the practice. In addition, some suggestions were made for the implementation process. The findings obtained about teaching process from the interview forms are presented in Table 2.

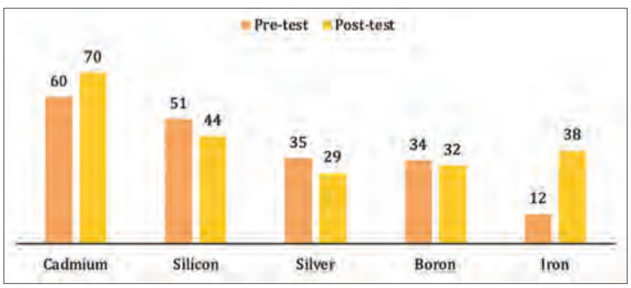

Figure 5: Prospective science teachers understandings about the chemicals that are pollutants of soil. The response rates for "nitrogen, calcium, sodium, phosphate, and carbon" were below 20%

About teaching process, most PSTs stated positive opinions for the ACL course (effective, entertaining, understandable, and so on). Few PSTs reported that the ACL course was boring and difficult and complex to understand in teaching process category as negative opinions. PSTS' opinions about FL approach are shown in Table 3.

When the codes about FL were examined, PSTs stated that preparation before lesson was efficient for reinforcing the subject was efficient. For this category, statements included negative opinions such as being preparation work exhausting and not being able to decide which information to take in this process. The limited suggestions by PSTs conflicted the nature of the planned teaching. These suggestions are presented in Table 4.

Only three PSTs made suggestions about implementation. These suggestions included pre-lesson quizzes, booklet for the whole term, and experiment report preparation.

DISCUSSION

This study aimed to investigate the effectiveness of the ACL course on enhancing PSTs' use of chemistry knowledge in interpreting and evaluating processes on environmental problems. Before implementation, there were deficiencies in PSTs' conceptual understanding of environment and environmental problems and in relating them to chemical

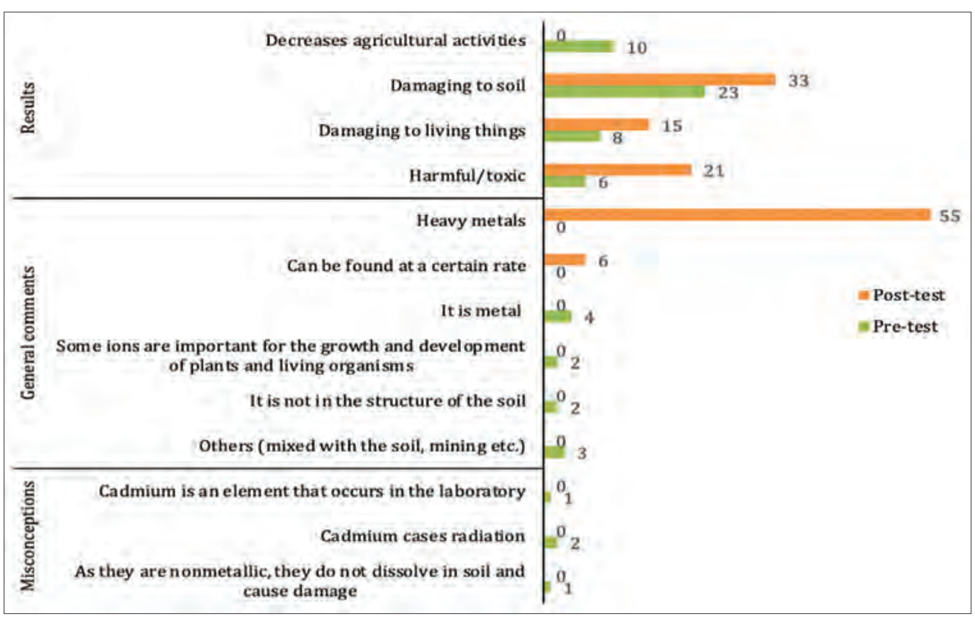

Figure 6: Prospective science teachers understandings related to the effect of chemicals on soil

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Table 2: PSTs' opinions on teaching process

	Positive Opinion		Negative Opinion		Examples
	Code	f	Code	f	
Teaching Process	Effective	29	Information is not useful for professional life	1	T1: The experiments we did in this course were very instructive and beautiful, entertaining experiments…
	Entertaining	26	Boring	6	T2: Our lessons were such that we could understand and comprehend. There was no experiment I couldn't understand
	Understandable	14	Rote learning	2	T6: I knew about environmental pollution, but I didn't know that much. I have learned this method and knowledge and will try to be more conscious
	Instructive	8	There was nothing to use in everyday life	1	T12: In the laboratory course I had the opportunity to see and understand the theoretical knowledge, I have seen knowledge in the laboratory in a practical and concrete way
	Simple experiments	1	Complex and difficult experiments to understand	5	T10: …It is a rather easily forgotten course because it is based on rote learning…
	Learn more about environmental pollution	3			T34. There was nothing to show the students in the future
	Opportunity to understand the theoretical knowledge in the laboratory	3			

Table 3: PSTs' opinions on flipped learning approach

	Positive Opinion		Negative Opinion		Examples
	Code	f	Code	f	
Flipped Learning	Finding preparation more effective for each lesson	11	Being preparation tiring for each lesson	5	T3: I think the way we handle the analytical chemistry laboratory course is very efficient. Learning the subject and solving the related questions before the experiments helps us to strengthen our understanding of the subject.
	An efficient process	10	Thinking the traditional laboratory practice more effective	1	T8: I wasn't stressed about the subjects I did not understand in pre-preparation, because I knew that I could understand in the course
	Reinforcing learning with planned phases	5	Difficulty conducting previously undescribed experiments	1	T9: Having the pre-preparation every week was a bit tiring, but it was good. It made us come prepared for class.
	A catchy course	4	Difficulty in deciding what information is needed during the preparation process	8	T37: The laboratory experiments were fun and beautiful, but I didn't understand what I should write and what parts were important when we were asked to do some preliminary study on the subject
	Beneficial	3			

Table 4: PSTs' suggestions on implementation

Suggestions	f
Rather than pre-preparation, quizzes at the beginning of each lesson would be better	1
It would be better to have a booklet or book about all processes instead of a copy every week.	1
Writing an experiment report on what had been done could have been more permanent.	1

knowledge. The fact that PSTs' opinions on pre-test regarding especially the environment and soil pollution were related to urban pollution category (Figures 2 and 4) was an indication that they associate pollution with visible and physical pollutants and their chemical knowledge was not sufficient for interpreting meaningful comments (Kıryak, 2013; and Said et al., 2007). After practices designed with FL approach, the codes and frequencies of chemical pollution category were a significant increase regarding soil pollution (Figure 4).

Concordantly, PSTs were able to think and interpret the chemical knowledge learned in laboratory practices, especially in the context of soil pollution. Similarly, PSTs replaced their superficial information on environment, soil, and water pollution in the pre-test with the ideas requiring higher-level and deeper information after implementation (Figures 2-4). For example, pre-test codes that came to mind easily (e.g., waste product and trash) that were revealed at high frequency under the urban pollution category were replaced with the codes that required more detailed thinking (e.g., heavy metals, agricultural activities, and chemical pollution) in the post-test (Figure 4). The fact that some PSTs' views on implementation included that they have learned more about environmental pollution (Table 2) supported the data obtained from CUT. Another remarkable point was that the frequencies of the codes related to pollution results have increased with FL practices (Figure 2). These findings indicated that the implementation process has changed PSTs' opinions on environmental problems to include their chemical knowledge and encouraged them to consider not only the causes of environmental pollution but also its consequences.

PSTs generated more meaningful opinions about the effects of the existence and amount of various chemicals in soil and water in the results category using chemical knowledge learned during practices (Figures 6 and 8). In addition, the alternative concepts identified in the pre-test under, both headings were not revealed after implementation. Concordantly, PSTs stated that they had the opportunity to experience theoretical knowledge practically thanks to FL practices and concretely and that this affected their learning positive way (Table 2). Herein, ACL course with FL approach produced effective results for the adaptation, interpretation, and inference of chemical knowledge and for the elimination of alternative concepts, and enabled PSTs to develop positive attitude by being aware of own development (DeSantis et al., 2015; Ryan and Reid, 2016; Roehl et al., 2013; and Tüysüz et al., 2017). The FL approach assisted PSTs to learn meaningfully and permanently by eliminating the deficiencies of traditional understanding such as using knowledge and learning independent (Davies et al., 2013; Hibbard et al., 2017; Ponikwer and Patel, 2018; and Roehl et al., 2013).

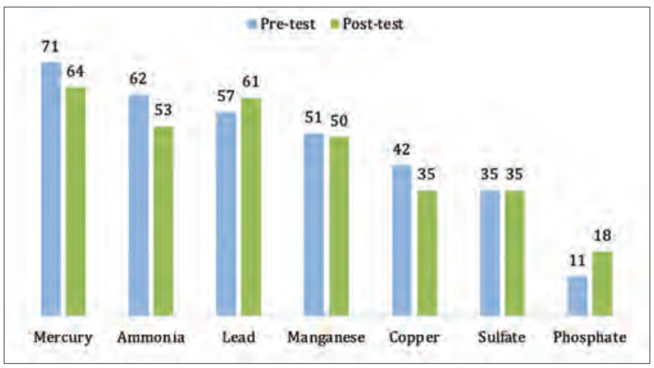

Figure 7: Prospective science teachers understandings about the chemicals that are pollutants of water. The response rates for "nitrogen, magnesium, oxygen, and chloride" were below 20%

Some PSTs had problems deciding on the information needed during the preparation process (Table 3). This situation showed that limits of the weekly topics drawn and verbal explanations by researchers were inadequate for those PSTs. The fact that the instructors clearly share the limits of the topics to be learned during the semester with the PSTs may prevent them from encountering these problems during the preparation process (Roehl et al., 2013). Moreover, the fact that the PSTs thought the preparation process tiring and ineffective and their suggestions for the teaching process were in accordance with the nature of the traditional understanding (Tables 3 and 4) showed that the PSTs tended to continue the teacher-centered understanding. Maintaining motivation that had at the beginning of the implementation throughout this long-term study was not easy for them. PSTs might have developed negative opinions about the practices when they were expected to reason and discuss about experiments, as they both less motivated and used to conducting experiments like a technician in accordance with pre-determined and drafted instruction (Hofstein, 1988). Overall, PSTs stated more positive opinions toward the course, despite the limited number of negative opinions. Data obtained from both CUT and forms indicated that the teaching process, which was carried out by adapting the FL approach into the ACL course, contributed to improving their conceptual understanding of content and developing their interpretation and evaluation skills related to environmental problems on the chemical context.

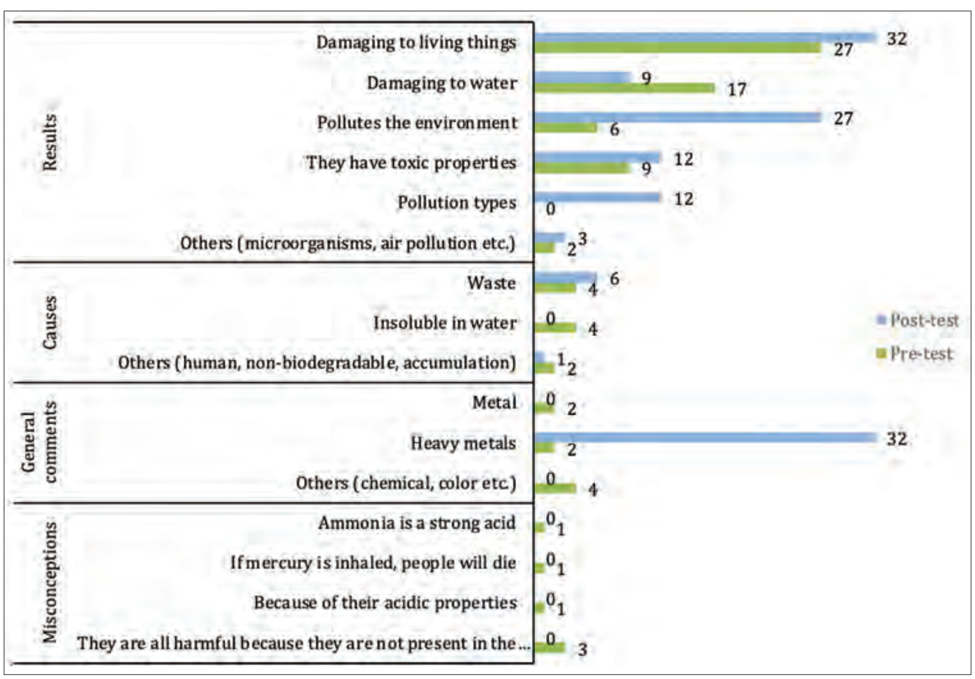

Figure 8: Prospective science teachers understandings related to the effect of chemicals on water

CONCLUSION

PSTs' interpretation ability related to environmental problems in the chemical dimension significantly improved thanks to ACL course designed with FL approach. Despite the increase in the PSTs' conceptual understandings, they could not reach a sufficient level especially in determining the pollutants in soil and water samples and explaining their thoughts. However, the positive change, although minor in PSTs' conceptual understanding and the realization that the knowledge, they learned was useful caused them to develop positive, thoughts about the laboratory course and contributed to their learning.

RECOMMENDATIONS

PSTs' chemical conceptual understandings were affected positively from the laboratory process by FL approach. In this respect, teaching processes which practice involving the teaching of socio-scientific issues (e.g., environmental pollution) designed in interrelated fields such as chemistry and biology will provide more effective results in terms of obtaining in-depth information and interpreting events in the light of scientific knowledge.

After the implementation, PSTs' ability to associate chemical knowledge with environmental problems increased. However, despite this increase, it was concluded that they could not reach a sufficient level in terms of producing solutions to environmental problems. The practices carried out within the scope of the ACL course have caused inadequacy in this regard, especially because experiments require a long time. Therefore, it was considered that there is a need for longer class hours, in which future implementations can be carried out for teaching and learning the solutions of environmental problems.

Reorganization of the traditional laboratory course in accordance with the nature of action research and its integration with the FL approach affected positively both PSTs' learning and opinions about the course. In this context, considering that the effectiveness of FL practices in the classroom which has been determined in various studies was also effective in the ACL, it is thought to be beneficial to use this approach in another laboratory course.

Some PSTs' negative opinions on preparation and lesson process and their suggestions pointed out that they wanted to obtain the information by rote learning from a traditional perspective. This situation revealed the need to re-motivate PSTs toward teaching during the implementation process. To deal with this situation, it is recommended that they go beyond the teaching processes that they are accustomed to by expressing the contributions of being more innovative and dynamic teachers and to be exposed methods and approaches, in which they can see the effects.

ETHICS DECLARATIONS

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Ethical Statement

All the procedures performed in studies involving human participants were in accordance with the ethical standards of the Institutional and/or National Research Committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Consent Statement

An appropriate consent form was used for the participants.

REFERENCES

Alkan, F., & Erdem, E. (2013). The effect of self-directed learning on the success, readiness, attitudes towards laboratory skills and anxiety in laboratory. *Hacettepe University Journal of Education*, 44(44), 15-26.

Ayas, A., & Özmen, H. (1998). *Level of Integration of Acid-base Concepts with Current Matters: A Case Study*. Trabzon: Paper Presented at the 3rd National Science Education Symposium.

Bajurny, A. (2014). *An Investigation into the Effects of Flip Teaching on Student Learning* (Unpublished Master's Thesis). Ontario Institute for Studies in Education of the University of Toronto. Available from: https://www.tspace.library.utoronto.ca/handle/1807/67002

Balkan-Kıyıcı, F., & Aydoğdu, M. (2011). Determination of pre-service science teachers' levels of relating the scientific knowledge to their daily lives. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, 5(1), 43-61.

Bergmann, J., & Sams, A. (2012). *Flip Your Classroom: Reach Every Student in Every Class Every Day*. International Society for Technology in Education.

Bokosmaty, R., Bridgeman, A., & Muir, M. (2019). Using a partially flipped learning model to teach first year undergraduate chemistry. *Journal of Chemical Education*, 96(4), 629-639.

Candaş, B., Doğan, M., & Mazlum, E. (2016). *Pre-service Science Teachers' Opinions about Analytical Chemistry Laboratory Through the Experiments*. Trabzon: Paper Presented at the 12nd National Science and Mathematics Education Congress.

Capobianco, B.M. (2007). Science teachers' attempts at integrating feminist pedagogy through collaborative action research. *Journal of Research in Science Teaching*, 44(1), 1-32.

Childs P.E., Hayes, S.M., & O'Dwyer, A. (2015). Chemistry and everyday life: Relating secondary school chemistry to the current and future lives of students. In I. Eilks & A. Hofstein (Eds.), Relevant chemistry education: From Theory to practice (pp. 33-54). Brill Sense.

Danker, B. (2015). Using flipped classroom approach to explore deep learning in large classrooms. *IAFOR Journal of Education*, 3(1), 171-186.

Davies, R.S., Dean, D.L., & Ball, N. (2013). Flipping the classroom and instructional technology integration in a college-level information systems spreadsheet course. *Educational Technology Research and Development*, 61(4), 563-580.

DeSantis, J., Van Curen, R., Putsch, J., & Metzger, J. (2015). Do students learn more from a flip? An exploration of the efficacy of flipped and traditional lessons. *Journal of Interactive Learning Research*, 26(1), 39-63.

Enfield, J. (2013). Looking at the impact of the flipped classroom model of instruction on undergraduate multimedia students at CSUN. *Tech Trends*, 57(6), 14-27.

Fitzgerald, N., & Li, L. (2015). Using presentation software to flip an undergraduate analytical chemistry course. *Journal of Chemical Education*, 92(9), 1559-1563.

Gilbert, J.K. (2006). On the nature of "context" in chemical education. *International Journal of Science Education*, 28(9), 957-976.

Hamdan, N., McKnight, P., McKnight, K., & Arfstrom, K.M. (2013). *The Flipped Learning Model: A White Paper Based on the Literature Review Titled a Review of Flipped learning*. Flipped Learning Network/Pearson/George Mason University.

Hart, C., Mulhall, P., Berry, A., Loughran, J., & Gunstone, R. (2000). What is the purpose of this experiment? Or can students learn something from doing experiments? *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science*

Science Education International
33(2), 192-202
https://doi.org/10.33828/sei.v33.i2.7

Teaching, 37(7), 655-675.

Hibbard, L., Sung, S., & Wells, B. (2016). Examining the effectiveness of a semi-self-paced flipped learning format in a college general chemistry sequence. *Journal of Chemical Education*, 93(1), 24-30.

Hofstein, A. (1988). Practical work and science education II. In: Fensham, P., (Ed.), *Development and Dilemmas in Science Education*. Bristol: Taylor & Francis. pp. 189-217.

Hofstein, A., & Lunetta, V.N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science Education*, 88(1), 28-54.

Karacop, A. (2017). The effects of using jigsaw method based on cooperative learning model in the undergraduate science laboratory practices. *Universal Journal of Educational Research*, 5(3), 420-434.

Kardas, F., & Yesilyaprak, B. (2015). A current approach to education: Flipped learning model. *Ankara University, Journal of Faculty of Educational Sciences*, 48(2), 103-121.

Kılınç-Alpat, S., Uyulgan, M.A., Özbayrak, Ö., & Alpat, Ş. (2011). A study on the effect of case-based learning for pre-service science teachers' attitudes towards an analytical chemistry laboratory experiment. *Buca Faculty of Education Journal*, 30, 1-19.

Kıryak, Z. (2013). *The Effect of Common Knowledge Construction Model on Grade 7 Students' Conceptual Understanding of "Water Pollution' Subject, Unpublished Master's Thesis*. Trabzon: Karadeniz Technical University.

Koçak, C., & Önen, A.S. (2012). Evaluation of chemistry topics within the daily life concept. *Hacettepe University Journal of Education*, 42(42), 262-273.

McCombs, B.L. (1996). *Understanding the Keys to Motivation to Learn*. Available from: http://www.educationmonitor.com/Understanding+the+Keys+to+Motivation+to+Learn-38.html

Miles, M.B., & Huberman, A.M. (1994). *Qualitative Data Analysis: An Expanded Sourcebook*. Sage.

Milner, A.R., Templin, M.A., & Czerniak, C.M. (2011). Elementary science students' motivation and learning strategy use: Constructivist classroom contextual factors in a life science laboratory and a traditional classroom. *Journal of Science Teacher Education*, 22(2), 151-170.

Muñoz-Campos, V., Franco-Mariscal, A.J., & Blanco-López, Á. (2020). Integration of scientific practices into daily living contexts: A framework for the design of teaching-learning sequences. *International Journal of Science Education*, 42(15), 2574-2600.

Nakhleh, M.B., & Mitchell, R.C. (1993). Concept learning versus problem solving: There is a difference. *Journal of Chemical Education*, 70(3), 190-192.

Niaz, M. (2005). How to facilitate students' conceptual understanding of chemistry? A history and philosophy of science perspective. *Chemical Education International*, 6(1), 1-5.

Ponikwer, E., & Patel, B.A. (2018). Implementation and evaluation of flipped learning for delivery of analytical chemistry topics. *Analytical and Bioanalytical Chemistry*, 410, 2263-2269.

Pooley, J.A., & O'Connor, M. (2000). Environmental education and attitudes: Emotions and beliefs are what is needed. *Environment and Behavior*, 32(5), 711-723.

Rigano, D., & Ritchie, S. (1994). Students' thinking in a chemistry laboratory. *Research in Science Education*, 24(1), 270-279.

Roehl, A., Reddy, S.L., & Shannon, G.J. (2013). The flipped classroom: An opportunity to engage millennial students through active learning strategies. *Journal of Family and Consumer Sciences*, 105(2), 44-49.

Ryan, M.D., & Reid, S.A. (2016). Impact of the flipped classroom on student performance and retention: A parallel controlled study in general chemistry. *Journal of Chemical Education*, 93(1), 13-23.

Said, A.M., Yahaya, N., & Ahdamun, F.R. (2007). Environmental comprehension and participation of Malaysian secondary school students. *Environmental Education Research*, 13(1), 17-31.

Schultz, D., Duffield, S., Rasmussen, S.C., & Wageman, J. (2014). Effects of the flipped classroom model on student performance for advanced placement high school chemistry students. *Journal of Chemical Education*, 91(9), 1334-1339.

Seery, M.K. (2015). Flipped learning in higher education chemistry: Emerging trends and potential directions. *Chemistry Education Research and Practice*, 16(4), 758-768.

Trogden, B.G. (2015). ConfChem conference on flipped classroom: Reclaiming face time-how an organic chemistry flipped classroom provided access to increased guided engagement. *Journal of Chemical Education*, 92(9), 1570-1571.

Tüysüz, M., Şardağ, M., & Durukan, A. (2017). The effect of inquiry-based learning approach on pre-service science teachers' analytical chemistry learning. *Van Yuzuncu Yil University Jounal of Education*, 14(1), 1657-1696.

Vos, M.A., Taconis, R., Jochems, W.M., & Pilot, A. (2010). Teachers implementing context-based teaching materials: A framework for case-analysis in chemistry. *Chemistry Education Research and Practice*, 11(3), 193-206.

Weaver, G.C., & Sturtevant, H.G. (2015). Design, implementation, and evaluation of a flipped format general chemistry course. *Journal of Chemical Education*, 92(9), 1437-1448.

Whisnant, D.M. (1982). Descriptive chemistry in the general chemistry laboratory: A learning approach. *Journal of Chemical Education*, 59(9), 792-794.

Wieman, C. (2015). Comparative cognitive task analyses of experimental science and instructional laboratory courses. *The Physics Teacher, 53*(6), 349-351.

Wilcox, B.R., & Lewandowski, H.J. (2016). Open-ended versus guided laboratory activities: Impact on students' beliefs about experimental physics. *Physical Review Physics Education Research*, 12(2), 020132.

Wong, S.S., Firestone, J.B., Luft, J.A., & Weeks, C.B. (2013). Laboratory practices of beginning secondary science teachers: A five-year study. *Science Educator*, 22(1), 1-9.

Yildirim, N., Ayas, A., & Küçük, M. (2013). A comparison of effectiveness of analogy-based and laboratory-based instructions on students' achievement in chemical equilibrium. *Scholarly Journal of Education*, 2(6), 63-76.

APPENDIX

Q1. What is environmental pollution?

Q2. What is water pollution? What are the sources of this pollution? Please give examples of pollutants.

Q3. What is soil pollution? What are the sources of this pollution? Please give examples of pollutants.

Q4. Nitrogen, calcium, iron, cadmium, sodium, potassium, phosphate, silver, boron, silicon, and carbon ions are included in a soil sample taken from a field where agricultural activities are carried out. Indicate which of these ions have a polluting effect. Please explain the reasons.

Q5. Water samples taken from a marine ecosystem with industrial facilities on the shore contain phosphate, lead, ammonia, mercury, sodium, copper, magnesium, oxygen, sulfate, manganese, and chloride ions. Indicate which of these ions have a polluting effect. Please explain the reasons.