

STUDENTS' PERCEPTIONS OF THE HISTORY OF SCIENCE AND TECHNOLOGY COURSE AT TEACHER TRAINING UNIVERSITY

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The article presents the integrated course “The History of Science and Technology” developed for the students of pedagogical universities, majoring in physics, mathematics, and computer sciences. The authors highlight the effective forms, methods and means of teaching the course. The qualitative research methods included observations, conversations with students, verbal and written surveys regarding course effectiveness; the quantitative methods applied testing of students’ progress. 56 students from Poltava V. G. Korolenko National Pedagogical University studying the course “The History of Science and Technology” and 53 students from National Pedagogical Dragomanov University attending the traditional courses, such as “The History of Mathematics”, “The History of Physics”, “The History of Computer Science” were involved in the experiment. The results show that important components for organising science history teaching and future pedagogical activities for students are assessment, developing and using teaching aids, and solving problems referring to history. The survey of teachers showed that the effectiveness of studying the course is mostly influenced by 3 main factors: enhancing students’ educational and cognitive activity in the process of introducing new material (76 %); solving problems referring to history during lectures, seminars and doing homework (62 %); doing individual tasks by students (56 %). The efficiency of the course “The History of Science and Technology” is achieved through: revising previously studied material at the beginning of the lecture; introducing problem-based learning; team teaching; individual tasks, summative assessment. The course “The History of Science and Technology” provides students with integrated knowledge about the development of science as well as the readiness to use historical information in future pedagogical activities in the conditions of STEM-education.

Keywords: history of science and technology; history of mathematics; future teachers of mathematics; physics; computer science, pedagogical university, STEAM-education.

Introduction

The globalisation in modern society has radically changed the content and structure of contemporary scientific knowledge. Modern pedagogical education is aimed not only at developing a certain system of competences in the narrow subject-practical sphere, but also at upbringing a harmonious personality, which will guarantee his/her efficiency, flexibility and mobility. Course developers should understand the place and role of changes taking place in scientific and cultural space, combine deep fundamental theoretical knowledge with practical training, freely orientate themselves in social, natural and educational processes, understand the specificities of cultural development, and overtake the scientific heritage.

According to Bevz (2005), Hodovaniuk (2009) and Florez et al (2019), the history of science may prove to be an effective means for updating the content of pedagogical education in the specified directions, since it is an integral part of the general culture, a necessary condition for the modern development of science, an important source of a complex of fundamental and humanitarian knowledge, a means to overcome contradictions between new and old knowledge, etc. As a separate subject, the history of mathematics was developed in the nineteenth century. Since then, teaching the subject has been constantly improving and, as a result, several approaches to developing the course have been formed: historical-chronological, subject-modular, historical-geographical, conceptual-logical, dominant, personified and combined (Bevz, 2005). In particular, the research paper by Furinghetti (2019) raises the problem about an efficient introduction of history in teaching, entails teachers’ historical knowledge.

In Ukraine, the course “History of Mathematics” is one of the constituents of the professional training of mathematics teachers. It is taught at classical and pedagogical universities. According to the curriculum, the course is included in the set of optional disciplines for professional training of specialists (the disciplines are approved by the university). The necessary basis for teaching the integrated course in history of mathematics is the preliminary mastery by students the following basic mathematical disciplines as algebra, geometry, mathematical analysis, probability theory, etc. For this particular reason, the course is taught to senior students.

The purpose of teaching “The History of Mathematics” at pedagogical universities is determined by two interrelated components: general scientific (to help students to master the history of the formation, development and transformation of mathematical science) and 2) professional (forming the historical and mathematical knowledge necessary for the future teachers of mathematics in order to solve correctly the methodical and methodological problems, arising in the process of teaching mathematics at school).

At the present stage of training the future teachers of mathematics at the National Pedagogical Dragomanov University, the course “The History of Mathematics” is included in the curriculum for Bachelor's degree. It involves lectures (compiled on a historical-chronological basis) and tutorials (worked out on a subject-modular basis), as well as an independent study of theoretical material. The Master's curriculum involves the course “The History and Methodology of Mathematics”.

At the Faculty of Physics and Mathematics at Poltava V. G. Korolenko National Pedagogical University, instead of a range of separate courses like “The History of Mathematics”, “The History of Physics”, “The History of Computer Science” future teachers of mathematics, physics and computer science, respectively, study the course “The History of Science and Technology”. The course is taught in the vast majority of technical universities.

The specificities of teaching this course were studied by Besov (2013), Mykhaylithenko (2013), Khramov (2017). For example, Besov (2013) provides a description of the course “The History of Science and Technology” (the process of integration of historical aspects of science and technology into natural and technical disciplines as well as social life) and proves the necessity to teach the course in Ukrainian higher educational establishments, since graduates will be able to gain the knowledge, which will expand their horizons, help to determine its value for humanity.

A new approach to the creation of the history of fundamental science is presented in the paper by Khramov (2017). He emphasises the necessity to understand the history of science as a set of fundamental ideas and thus to create an innovative science of history. For this purpose, Khramov (2017) proposed the following structure of the course: the history of the internal logic of the science development (the genesis of its ideas, theories, discoveries); biography studies; chronology; history of scientific institutes, laboratories, designing departments, academies of sciences, academic communities (social history); the history of scientific schools; the history of science in archival documents and materials.

The curriculum of the course “The History of science and technology” for students of pedagogical specialities is provided in the textbook by Mykhaylithenko O. V. (2013) with the corresponding title. The author in detail examines the origins of science, the development of technology in the history of mankind and the history of science as a form of social consciousness. At the same time, the manual does not define the purpose and function of this course for the development of the student's personality and the formation of future competent specialists with the corresponding competences. For example, Bunch & Helleman (2004) research paper called “The history of science and technology: a browser's guide to the great discoveries, inventions, and the people who made them, from the dawn of time to today”, provide interesting historical parallels and emphasise the continuum in development of science and technology.

The consideration of the above-mentioned research papers as well as personal work experience in the pedagogical university allow to conclude that the course “The History of Science and Technology” contains information on the development of specific scientific fields (mathematics, physics, engineering, technology, engineering, etc.) and science in general. Awareness of the history of science and technology and the ability to use the knowledge acquired in teaching students makes it possible to implement an axiological approach in the education system.

At present, the relevance and timeliness of introduction of this course into the professional training of future teachers, in particular teachers of mathematics, physics, and computer science are conditioned by the changes taking place in the system of secondary education, for instance, by the so-called “STEM-education” (S – Sciences, T – Technology, E – Engineering, D – Design, M – Mathematics) (Margot & Kettler, 2019; Herro & Quigley, 2017). STEM-oriented approach to teaching is a combination of interdisciplinary, practically oriented approaches to the study of natural and mathematical disciplines (Stryzhak et al, 2017; Pimthong & Williams, 2018). In this context, the project of STEM-education in Ukraine claims that the role of a teacher is not only to transfer knowledge, but also to teach culture and human values, national ideas and democratic changes. In teacher training, it is important to implement interdisciplinary connections, i.e. to prepare specialists who realise the importance of professional knowledge in the context of socio-cultural space. The teacher's ability to organise the educational process as a pedagogical interaction aimed at developing the student's personality, preparing a student for solving the problems of everyday life is of paramount significance (The Project of the Concept of STEM Education in Ukraine, 2017). The course

“History of Science and Technology” will contribute to the introduction of the elements of STEM-education by understanding the past and present achievements of mankind.

The **purpose** of the article is to reveal the students' perceptions on the course “The History of Science and Technology” in the context of interdisciplinary synthesis, which is becoming relevant in modern science. The main tasks of the article are: to establish a rational structure of the educational course “The History of Science and Technology”, to highlight the effective forms, methods and means of teaching the suggested course; to study and compare the attitude of students of pedagogical universities to the educational courses “The History of Mathematics” and “The History of Science and Technology”.

Method

This is a mixed study using qualitative methods based on observations, conversations with students, verbal and written surveys and quantitative methods which applied testing of students' progress.

I. Participants

The experiment was held among two different groups of respondents:

Group 1: the students of the faculty of physics and mathematics of both pedagogical universities (fourth year of study). Thus, 56 students from Poltava V. G. Korolenko National Pedagogical University and 53 students from National Pedagogical Dragomanov University were involved in the experiment.

The students had the opportunity to express their attitude to each educational topic and the suggested the activities in the course of the interview. At the end of the survey, it was determined how the proposed courses contribute to the formation of students' readiness to use historical material in further pedagogical practice.

Group 2: teaching staff of pedagogical universities. Five instructors were involved who teach the history of mathematics, physics, computer science, as well as the history of science and technology.

Teachers were encouraged to express their views on the possibility of introducing “The History of Science and Technology” course for future teachers instead of separate courses “The History of Mathematics”, “The History of Physics”, “The History of Computer Science” and to identify the factors that, in their opinion, have the greatest influence on preparation for future pedagogical activity.

II. Apparatus and materials

Course structure

The purpose of the academic discipline “The History of science and technology” is to form a sufficient level of knowledge about the historical development of science, to develop skills and abilities to apply the acquired information from the history of science and technology in a future pedagogical career as well as to develop the students' scientific views.

The following basic tasks of teaching the discipline “The History of Science and Technology” were set: to reveal the laws of scientific and technological development from ancient times to the present, to establish the stages of development of science and technology and to provide their defining features; to determine the place of science and technology in social life; to use the latest achievements of the history of science and technology in teaching the course and to familiarise students with the findings of the leading scientific centres in the field of science and technology in Ukraine; to inform students about the specifics of intellectual scientific and engineering activities, to show the role of the scientist's personality in the scientific and technological progress of mankind; to develop in future specialists the skills to analyse historical sources and scientific literature independently as well as the ability to comprehend the laws of development of the history of science and technology, to promote applying the acquired knowledge in future pedagogical practice.

The course curriculum presupposes 24 hours of lectures and 12 hours of seminars and comprises 8 main themes:

Theme 1. The History of Science and Technology as an academic subject.

Theme 2. Science and Technology of the Ancient World and the Age of Antiquity.

Theme 3. The development of scientific thought in the Middle Ages.

Theme 4. The development of science and technology in the Renaissance.

Theme 5. Establishing the foundations of classical science in the New Age Epoch (XVIII – XIX centuries). Industrial revolution.

Theme 6. The latest revolution in the late nineteenth and early twentieth centuries.

Theme 7. The scientific and technological revolution of the second half of the twentieth century.

Theme 8. The period of modern science and technology in the world and in Ukraine.

The distinctive feature of the programme of the course is the fact that it considers the development of science in Ukraine, as well as emphasises the issues related to the place and significance of the history of science and technology in the professional training and the work of future teachers. In this context, special attention should be paid to the distribution of questions for self-directed work – students independently worked out the educational material on the history of the development of scientific knowledge in the corresponding field (mathematics, computer science and physics).

Assessment of students' perceptions on the course

1. Students' progress was evaluated in the course of continuous verbal and written assessment; the results of independent work and the performance of an individual task, testing, etc. were as well taken into account. Using such a system of integrated assessment while teaching the history of science, provides not only control, but also motivation to study and the students' responsibility for the results obtained; it also contributes to the best achievements and qualitative knowledge acquisition. For example, written test, among other tasks, implied providing answers to the following questions:

- Determine which century the given object or discovery is dated.
- Which scientific branch does the given scientist refer to?
- Identify a quotation: 1) of a famous mathematician (a physicist, a computer scientist); 2) about the given scientific field; 3) about the activities of a prominent scientist.
- Provide the time and place of a given historic event.
- Make a chronological table of life and creative work of two scholars.
- Give examples of two historical works, characterise their author, place and time of creation. Provide the keys and methodological guidance for students and teachers.
- Write a detailed lesson plan and extracurricular event scenario using historical material. Work out computer presentations to them.

At the end of the course, students passed computer tests.

In order to make corrections to the developed course structure and to determine the ways of its implementation in practice, it was necessary to figure out the students' attitude towards the components of the proposed structure of the course. For this purpose, after completing the course each student was offered a questionnaire where the students had to arrange the components listed below according to their impact on the professional development.

- 1) students' active participation at seminars and lectures;
- 2) developing and using teaching aids;
- 3) assessment;
- 4) solving problems referring to history;
- 5) discussing scientific discoveries in different periods of development of mathematics, computer science and physics in the form of a business game;
- 6) creating and implementing the educational technologies in teaching the history of science and technology;
- 7) evaluating the lessons held by teachers;
- 8) discussing the contribution of prominent scientists (Ukrainian in particular) to the development of science and technology.

2. All instructors involved in the survey were provided with a syllabus on “The history of science and technology” course as well as the appropriate methodological guidance. They could share their own views as for the introduction of the integrated course in the history of science. They identified in practice the possibility of combining the teaching material concerning the history of mathematics, the history of physics, the history of computer science, with information relating to the history of science in general.

III. Procedure

At Poltava V. G. Korolenko National Pedagogical University a new course “The History of Science and Technology” was introduced. This course is optional for students in the fourth year of studying, and is taught in the second semester according to the Bachelor's curriculum for future teachers of mathematics, physics and computer science.

To effectively study the history of science and technology, students had free access to the necessary literature and teachers' lectures, presentations and texts on relevant topics. Students independently prepared presentations on seminar tasks, as well as sources and questions that were discussed after the coverage of the programme material. Students, as future teachers of mathematics, physics and computer science, were

encouraged to work out individual tasks on the discipline “The History of Science and Technology”, which in future could be useful for them when teaching in secondary educational institutions.

At National Pedagogical Dragomanov University students were offered to study the traditional courses, such as “The History of Mathematics”, “The History of Physics”, “The History of Computer Science” and the lectures in these courses contained some separate elements from the history of science and technology. For instance, the following issued were studied:

- the mechanisms developed by Archimedes (screw, milling machine, odometer).
- computing machines created by Shikkard, Pascal, Leibniz, Babbage);
- Leonardo da Vinci (architecture and mathematics, anatomy and mathematics, astronomy and mathematics, geography and mathematics);
- Niccolo Tartaglia and his work on the theory of artillery;
- Gutenberg’s production of the first printing press;
- the telescope and the mechanical watch with Huygens’ pendulum, etc.

Besides, as individual task students described 2 inventions made in the nineteenth century.

Teachers who participated in the survey had the opportunity to express their views on the factors that, in their opinion, influence the historical-mathematical and professional training of future teachers in the process of studying a systematic course in the history of mathematics (physics, computer science) or the history of science and technology. For this purpose, they were asked to rank 6 factors:

- 1) face-to-face questioning at the beginning of the lecture on questions discussed at previous lectures and studied by students independently;
- 2) updating the educational and cognitive activity of students by a good combination of information and problematic questions in the process of reviewing new material;
- 3) pair lectures (teacher + student);
- 4) solving of historical tasks during lectures, seminars and homework;
- 5) checking the educational achievements through tests;
- 6) doing individual tasks by students.

The hypotheses put forward during the survey should be tested and refined based on the results of the final control of students’ educational achievements.

Results

During the study, it was established that future teachers of mathematics are not always aware of the purpose to study the history of science and technology, not everyone can give specific examples of the use of the obtained information in further pedagogical practice. Written tests showed that the greatest difficulties arose in the process of writing detailed lesson plans and scenarios of extracurricular activities using historical material. Almost 20 % of students were not able to perform these tasks at all, and 12 % partly performed them or had errors.

At the same time, as the experiment showed, students carried out individual tasks related to technical inventions with pleasure. The presentation about the telescope of I. Lippershey, the invention by Belgian J. Lenuar of the internal combustion engine, the creation of IBM’s first personal computer company and others proved to be very interesting (see also Dmytrienko, 2018; Das et al, 2019).

According to the results of the survey, it was found that 3 major factors were the most influenced by the historical-mathematical and professional training of future teachers when studying courses in the history of mathematics (physics, computer science) or science and technology. These factors are: enhancing students’ educational and cognitive activity in the process of introducing new material (76 %); solving problems referring to history during lectures, seminars and doing homework (62 %); doing individual tasks by students (56 %). Other factors mentioned in the “Procedure” received the following values: face-to-face questioning at the beginning of the lecture on questions discussed at previous lectures and studied by students independently (22 %); current and final test revision of academic achievement (17 %); pair lectures (teacher + student) (7 %).

On the basis of programme of course “The History of Science and Technology” and comparing it with existing courses “The History of Mathematics” “The History of Physics”, “The History of Computer Science”, the teachers who participated in the survey expressed the opinion about the possibility of combining educational material related to the history of mathematics, history of physics, history of informatics, with information concerning the history of science in general. One respondent noted that the course “The History of Science and Technology” should be supplemented with separate topics related to the subject of students’ teaching in the future.

The obtained results allow claiming about the expediency of implementing the course “The History of Science and Technology” to the students of the Faculty of Physics and Mathematics of pedagogical universities. As an alternative, the courses “The History of Mathematics”, “The History of Physics”, “The History of Computer Science” could be completed with some general questions about the development of science and the most significant discoveries and inventions in technology.

Each of the suggested courses has its advantages. Introduction of integrated course “The History of Science and Technology” is relevant in the context of the introduction of STEM education and significant cost savings for the university, as it is possible to combine multiple streams for lectures.

Students’ attitudes towards the individual components of the proposed course structure and the impact of the training course on the formation of the readiness of future teachers of mathematics to use historical material in future pedagogical activity are indicated by the results of the questionnaire presented in Fig. 1.

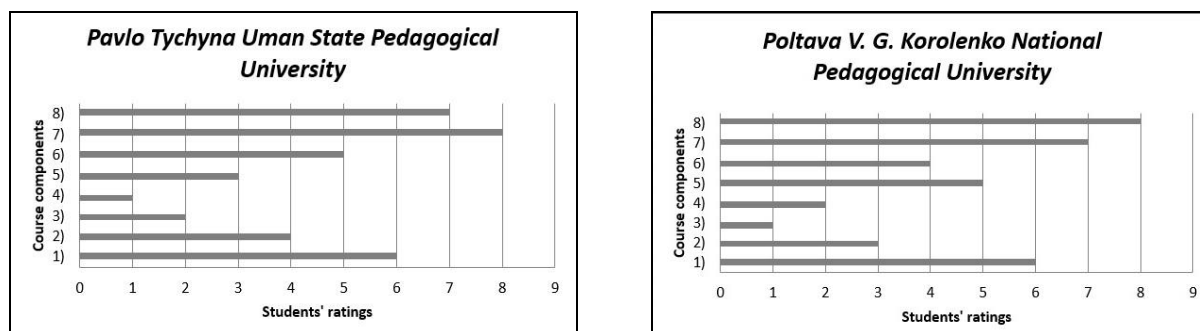


Figure 1. Students’ attitudes to the individual components of the proposed course

The bar chart illustrates the students’ attitudes to the individual components of the proposed course “The History of Science and Technology”. The vertical axis shows the course components mentioned in the Methods section. The horizontal axis represents students’ ratings of the course components depending on their relevance and importance. As the bar chart shows, students from both universities ranged the same components in the first and last place, respectively (1 – assessment; 8 – discussing the contribution of prominent scientists (Ukrainian in particular) to the development of science and technology). There are no significant differences in the attitude of students at the two universities about three components: 1) students’ active participation at seminars and lectures; 2) developing and using teaching aids; 3) solving problems referring to history. It is also important to note the preparation for solving historical problems in teaching practice depend both on teachers and students.

Discussion

The research allows claiming that the development of the course “The History of Science and Technology” and its introduction into the educational process of future teachers of mathematics in pedagogical universities are relevant and timely. Throughout its centuries-old history, science and technology have accumulated a wealth of factual material that requires comprehension and systematisation. The course in the history of science and technology should be presented to students to create a clear, adequate, and unambiguous view on the true path of science and technology. Teachers should consider fundamental ideas, theories, laws; key discoveries that have had an especially significant impact on the development of a particular scientific field.

As compared to the courses “The History of Mathematics”, “The History of Physics” and “The History of Computer Science”, the integrated course in “The History of Science and Technology” has significant advantages: firstly, it enhances the level of general culture and acquisition of relevant professional competences of future mathematics teachers; secondly, the course ensures the formation of a coherent scientific worldview of students, provides them with universal knowledge and skills that will contribute to the introduction of the elements of STEM – education by understanding the development of past and present achievements of mankind; and, finally, the course can be introduced to students of several specialities (mathematics, physics, computer science).

At present, at the vast majority of physics and mathematics faculties of pedagogical universities in Ukraine the curriculum “Bachelor. Secondary education” comprises the following courses: “The History of Mathematics”, “The History of Physics” and “The History of Computer Science”. The research, as well as the validation and promotion of its results, will hopefully have a positive impact on changes in the curriculum to be implemented, namely, introduction of the integrated course “The History of Science and Technology”.

Conclusions

The modern education system requires training the teacher of a new generation, who has a high level of general and professional culture. Modernisation and improvement of the system of education at pedagogical universities can be realised on the basis of the implementation of an integrated approach to teacher training. The history of science and technology could be chosen a good example of integration, since acquiring this discipline provides understanding the science as a complex system, its internal and external connections, ways and prospects of development. The knowledge of science and technology acquired by students can become in the future the background for teaching integrated courses at school, for the organisation of interdisciplinary research at the Small Academy of Sciences, for raising pupils' interest in engineering specialities (relevant in the context of STEM-education), etc.

The specificities and the complexity of the course "The History of Science and Technology" are conditioned, on the one hand, by the subject and content of science and on the other hand – by the tasks of this discipline in the context of modern requirements to the professional training of future teachers. The course can contribute to the formation of scientific views, the general culture and professional competence of future specialists, as well as help them in their further professional practice.

Thus, the need to solve the problem with regard to the structure, content, quantity of tutorial hours and forms of organisation of the integrated training course "The History of Science and Technology" for future teachers of mathematics, physics and computer science is an urgent and timely issue. Another relevant task is to improve the methodology of teaching the course "The History of Science and Technology" by means of information and communication technologies and modern educational trends.

Further studies may potentially relate to the development of methodological guidance for the course "The History of Science and Technology" and its introduction into the educational process of other pedagogical universities. Moreover, it is advisable to build and implement a distance course in "The History of Science and Technology" for future and current mathematics teachers.

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