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Methods of Developing Research Skills Through Interactive Digital Laboratories in Physics Education

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Abstract

This article presents with a simple and systematic approach the methodology for developing students' research skills through interactive digital laboratories in teaching physics. In the changing information and communication environment in modern pedagogical conditions, it remains important for students to independently form their knowledge, conduct experiments, collect information, analyze and draw conclusions. Interactive digital labs (e.g. simulations, virtual experiments, digital touch modules) create a methodologically efficient platform to support this process. Firstly, the article explains the role and basic principles of digital laboratories in the educational process, the second is the structure and basic stages of research skills, and the third is the system of methodological recommendations for the formation of these skills using interactive digital laboratories. Also on practical terms, model stages and problems, as well as measures to overcome them are addressed. This approach serves to awaken students' scientific thinking in the world of pedagogy and physics education and to stimulate independent research.

Keywords: Physics education, digital lab, interactive experiment, research skills, visual-modeling, teaching methods, virtual lab, independent student activity.

Introduction

In the 21st century educational environment, the process of learning is not limited to traditional lectures and one-on-one experiences, but is moving to an actively engaging, interactive, research-oriented form of learning. Especially in the context of physical science, there is a growing need to develop students' research skills (independent observation, modeling, experimentation, analysis and generalization of the result). On the other hand, digital technology is greatly enriching the education process. Digital labs – virtual or interactive component experiments – provide students with an environment that is similar to real-world experiences, but more open to visual modeling and testing. For example, the PhET Interactive Simulations project serves to reinforce students' basic conceptual understanding through interactive simulations. However, recent research confirms the theoretical effectiveness of digital labs – for example, it has been shown that virtual experiments can increase students' conceptual understanding and practical skills. In this context, the use of interactive digital laboratories as a methodology for the development of research skills in physical education is an urgent pedagogical issue. This article methodically analyzes this approach, offers practical recommendations, and provides its use for teachers and methodologists. Research skills are important points in preparing students for self-discovery in a subject matter. These skills can be categorized as follows:

1) identify the problem and formulate a research question;
2) modeling and forecasting;
3) conducting experiments or observations, collecting information;
4) analyzing and displaying information with the help of graphs, tables, visual models;
5) summarizing the results and moving the problem to the next level.

Digital labs can act as an interactive tool in each of these phases. For example, a learner deepens their understanding of a problem in a digital simulation environment through visual modeling: they can change different parameters, see the results, and compare them with an estimate. This process serves to combine the stages of modeling and forecasting. Digital labs are also safer than real-world experiments, easy to reproduce and allow them to work with a variety of errors – thus encouraging students to explore freely during the experimental phase.

Methodologically, using interactive digital laboratories in physics lessons is recommended to be carried out in the following stages:

Phase 1: Pose and guess the problem. Students are asked a question, a problem, or a research question. In the digital laboratory environment, a corresponding modeling scenario is created – the students set parameters, the simulation begins and the results are recorded. At this stage, pupils' skills of guessing, problem modeling and visualization are formed.

Phase 2: Conducting experiments and data gathering. In a digital lab environment, students experiment with different parameters in a visual environment close to real experience, tracking results using sensors or digital graphs. At this stage, the skills of collecting and systematically conducting information are developed. For example, in digital experiments, variables can be identified, errors can be evaluated, and repeated tests can be performed.

Stage 3: Analyze , improve modeling, and draw conclusions. Students analyze the collected data with the help of visual graphics, compare it with the results of modeling, evaluate errors and set new parameters for improvement. This stage is specific to scientific research – once a problem has been identified, it allows independent research and extension by the readers. Digital labs stand out as a visual-modeling platform at this stage: further solidifying scientific thinking skills through graphics, animations, and interactive components.

One of the important points of the methodological recommendation is that the role of the teacher changes as a specialist-moderator. Whereas in a traditional lesson, the teacher will carry out only visual activities, whereas in digital labs he will be the one who organizes, guides, coordinates the students' work on a technological platform, organizing their independent research process. This role involves supporting the activity of learners in a visual-modelling and experimental environment: selecting parameters, making assumptions, comparing test results, analyzing and experimenting with errors. This approach develops research-specific metacognitive skills in students: planning their own work, monitoring outcomes, adapting to change, and coordinating research with colleagues. Interactive digital labs can also be used for individual and group work. Organization of modeling and experiment processes in a group format in a cooperative way, which contributes to the formation of students' skills of communicative and teamwork. In visual-modeling, students present results using graphics, intervene in parameters through interactive elements, discuss their own assumptions, errors, and possible results – which expands their scientific thinking and problem-solving skills.

In practical terms, for the application of the methodological process at the school, gymnasium, or high school stages, there are the following recommendations:

When choosing a digital lab environment, students should choose software or online platforms appropriate to their age and level of knowledge, with high interactivity and the ability to adjust variables;

integrate visual-modeling into the lesson plan, for example, pose a problem, model, make changes to parameters, observe the results, discuss and plan the conclusion sequence;

Stimulating active research of students, providing questions and challenges that allow students to explore beyond literal instruction and explore their own assumptions;

establish a process of defining roles within the group and collaboratively based modeling;

to prepare teachers and students the necessary technical aspects (computers, sensors, Internet connection, software) to work in a digital laboratory environment;

In addition to traditional tests, the use of rubrics for the assessment of work results, which take into account students' activities, assumptions and tests in the modeling process, group skills and scientific skills.

Research shows that digital labs serve to improve students' conceptual understanding of physics and encourage independent activity in their experimental environments. However, there are some problems in methodological practice – the need for infrastructure for the creation of digital laboratory environment, adaptation to software, digital competencies of teachers and adaptation of students to technology. These aspects should be carefully considered within the structure of methodological recommendations.

In conclusion, in physics education, the methodology of developing students' research skills with the use of interactive digital laboratories is a proven approach that is in demand in the modern educational environment, the effectiveness of which has been proven in scientific research. Digital laboratories provide students with the opportunity to independently and actively study experimental and modeling processes, deepen their understanding of complex physical phenomena through visual modeling, and form scientific thinking. At the same time, the role of the teacher has been methodologically updated: it emerges as a diverse role – a guide, a supporter of the research process, and a co-ordinator of the technological platform. Important factors for the implementation of the methodology are infrastructure, digital competencies of teachers, technology preparation of students and modernization of assessment systems. In the future, the process of integration of digital laboratories into education environment and the formation of research skills will become relevant in modern schools and higher education.

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