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# ORGANIZING PHYSICS EXPERIMENTS USING VERNIER DIGITAL SENSORS: A METHODOLOGICAL APPROACH

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## ABSTRACT

This study examines the organization of school physics experiments using Vernier digital sensors and explores students' reported attitudes towards sensor-supported laboratory activities. The study involved 39 tenth-grade students and used a questionnaire, classroom observation, practical laboratory activities, and quantitative analysis of categorical responses. The questionnaire contained 10 items addressing students' interest in digital sensors, perceived usefulness, previous experience, and familiarity with the equipment. The source data indicate that 31 students (79.5%) described the use of digital sensors as very interesting, while 26 students (66.7%) considered sensor-supported investigation very effective. The manuscript also presents a laboratory activity using current and voltage sensors to investigate the relationship described by Ohm's law. Cross-tabulations were re-examined using a conditional Monte Carlo procedure because several expected cell counts were small. Only the association between students' interest and previous experience with sensors reached the nominal 0.05 level; none of the four comparisons remained significant after Bonferroni adjustment. The findings therefore provide exploratory, descriptive evidence of students' perceptions rather than proof of a causal improvement in achievement. The study illustrates how digital sensors can support real-time data collection and graphical interpretation in school physics, while highlighting the need for clearer reporting and further controlled research.

**Keywords:** Vernier Digital Sensors; Physics Education; Digital Experiments; STEM Education; Laboratory Work; Experimental Skills.

## 1 INTRODUCTION

Experimental investigation is central to physics education because many physical concepts are developed and tested through observation, measurement, and the interpretation of evidence. In school laboratories, students are expected to connect theoretical descriptions with measurable quantities, identify relationships between variables, and formulate conclusions based on experimental results.

Traditional laboratory activities commonly involve manual readings, handwritten records, and the construction of graphs after measurements have been collected. These procedures remain valuable for developing measurement skills. However, when a phenomenon changes rapidly or requires repeated measurements, manual data collection may limit the amount of evidence that students can examine during a lesson. Real-time microcomputer-based laboratory tools

can collect and display data as an experiment proceeds, allowing learners to focus on patterns and relationships in the measured quantities [2].

Vernier digital sensors and interfaces provide a means of collecting data in school and university science experiments. Depending on the sensor and interface used, measurements can include position, velocity, acceleration, temperature, force, pressure, voltage, and electric current. Vernier's physics resources describe experiments using motion detectors, force sensors, light sensors, magnetic-field sensors, photogates, and temperature probes [3]. The Vernier system has also been described in the context of practical laboratory training in higher education [4].

The use of digital measurement tools is relevant to inquiry-oriented physics teaching. In such activities, students can make predictions, collect evidence, represent results graphically, and compare observations with theoretical expectations. Earlier work on real-time microcomputer-based laboratories discussed the potential of immediate graphical feedback to support students' investigation of motion concepts [2]. Current educational resources also describe the use of Vernier Go Direct sensors with graphing technology for collecting and analysing experimental data [5].

Digital equipment does not, by itself, ensure effective learning. Students need to understand what a sensor measures, how the measurement is represented, and what limitations may affect the data. Teachers therefore need to provide clear instructions, demonstrations, and opportunities for students to interpret measurements rather than simply observe automatically generated graphs. Research on active-engagement approaches in physics education also emphasizes the importance of connecting instructional methods with students' conceptual development [6].

In Kazakhstan, the modernization of education and the development of research competencies are addressed in national policy documents, including the Concept for the Development of Higher Education and Science for 2023–2029 [1]. Within this broader context, the use of digital measurement systems in school physics provides one possible way to organize practical work and support students' engagement with experimental evidence.

The purpose of this study was to examine the organization of physics experiments using Vernier digital sensors and to describe tenth-grade students' reported attitudes towards their use. The study addressed the following questions: (1) How did participating students assess the interest and perceived usefulness of sensor-supported physics activities? (2) How were students' interest, prior experience, and familiarity with sensors distributed across the questionnaire categories? (3) How can a laboratory activity using current and voltage sensors be organized to investigate Ohm's law?

## 2 MATERIALS AND METHODS

### 2.1 Research design and participants

The study used an exploratory descriptive design combining a questionnaire survey, classroom observation, practical laboratory activities, and quantitative analysis of categorical responses. The study was conducted at Abai School in Turkistan, Kazakhstan, during April–May 2026. The participants were 39 tenth-grade students (N = 39). The research activities were organized under a tripartite agreement involving the students' parents or guardians, the school administration, and the university.

### 2.2 Questionnaire

The questionnaire consisted of 10 items, each with three response options. The items addressed students' interest in digital sensors; their views on the usefulness of investigating physical phenomena with sensors; the perceived importance of Vernier-supported experiments; the influence of digital tools on lessons; previous experience with sensors; attitudes towards computer-based data processing and graph construction; familiarity with Vernier sensors; understanding of sensor functions; the usefulness of automatically collected data; and interest in laboratory activities. The complete wording of all 10 items and their response options was not included in the supplied manuscript. The final submission should include the questionnaire as a supplementary file or reproduce it in this section.

### 2.3 Classroom observation and practical activities

During physics lessons, students' participation, practical task performance, ability to use the equipment, and engagement were observed. The source manuscript reports laboratory activities involving measurements of temperature, pressure, light-related quantities, and motion. It also describes an electrical investigation using Vernier current and voltage sensors. The supplied file does not specify the exact sensor models, interface, software version, sampling rate, calibration procedure, or observation rubric. These details should be added if they were recorded.

### 2.4 Data analysis

Item-level results were summarized as frequencies and percentages. Four 3 × 3 contingency tables from the source manuscript were used to examine the relationships between interest and perceived effectiveness, interest and previous experience, sensor familiarity and interest, and perceived effectiveness and attitudes towards automated data collection. Pearson chi-square statistics were calculated as descriptive test statistics. Because expected cell counts were small in each table, p-values were estimated using a conditional Monte Carlo procedure based on 500,000 random tables with the observed marginal totals fixed. Bonferroni adjustment was applied across the four exploratory comparisons. The calculations were performed from the cell frequencies displayed in the supplied manuscript; they should be checked against the original participant-level dataset before submission.

### 2.5 Ethical considerations

The study was conducted under a tripartite agreement involving the students' parents or guardians, the school administration, and the university. The agreement established the arrangements for conducting the educational research activities with the participating students. No separate institutional ethics approval number or individual consent/assent procedure is stated here; such details should be added only if supported by the study records.

## 3 RESULTS AND DISCUSSION

### 3.1 Students' interest in digital sensors

According to the item-level results reported in the source manuscript, 31 students (79.5%) considered the use of digital sensors very interesting, three (7.7%) reported that they were interested only in certain situations, and five (12.8%) indicated that the activity was not very interesting. These responses suggest that most participants viewed sensor-supported work positively. The distribution is presented in Figure 1.

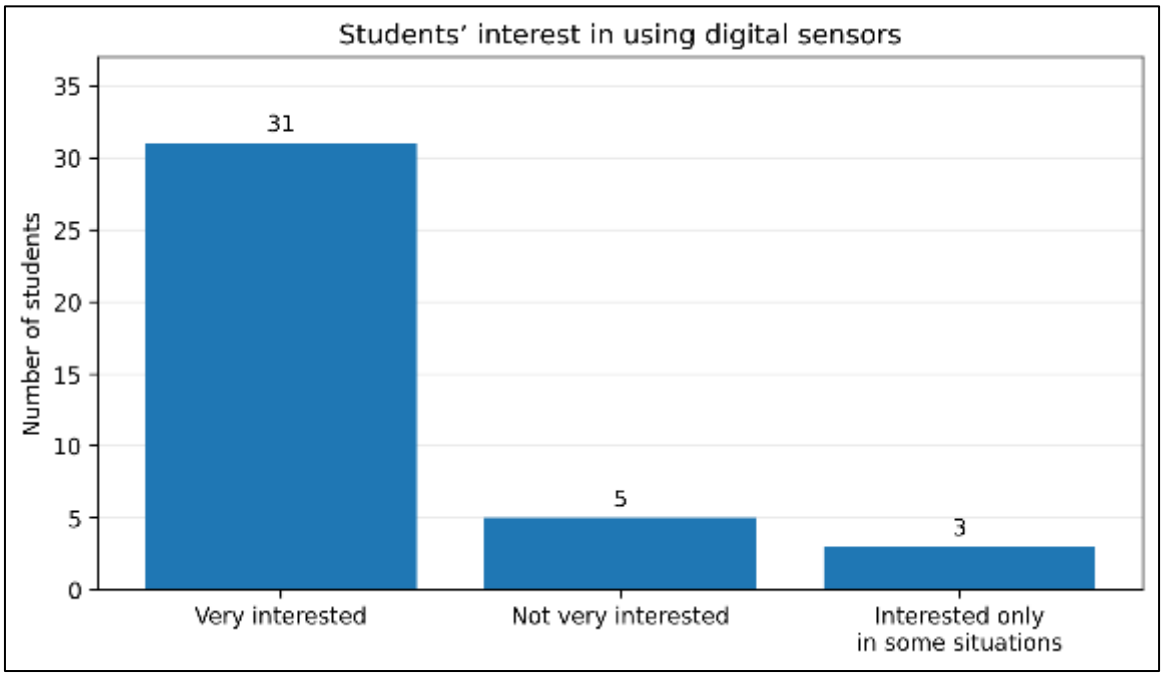



**Figure 1: Students' interest in using digital sensors in physics lessons.**

### 3.2 Perceived effectiveness of sensor-supported investigation

For the item concerning the effectiveness of investigating physical phenomena with digital sensors, 26 students (66.7%) selected the most positive response, seven (17.9%) considered the approach effective only in some situations, and six (15.4%) indicated that theoretical explanation alone was sufficient. These results describe students' perceptions and should not be interpreted as a direct measure of learning achievement (Figure 2).

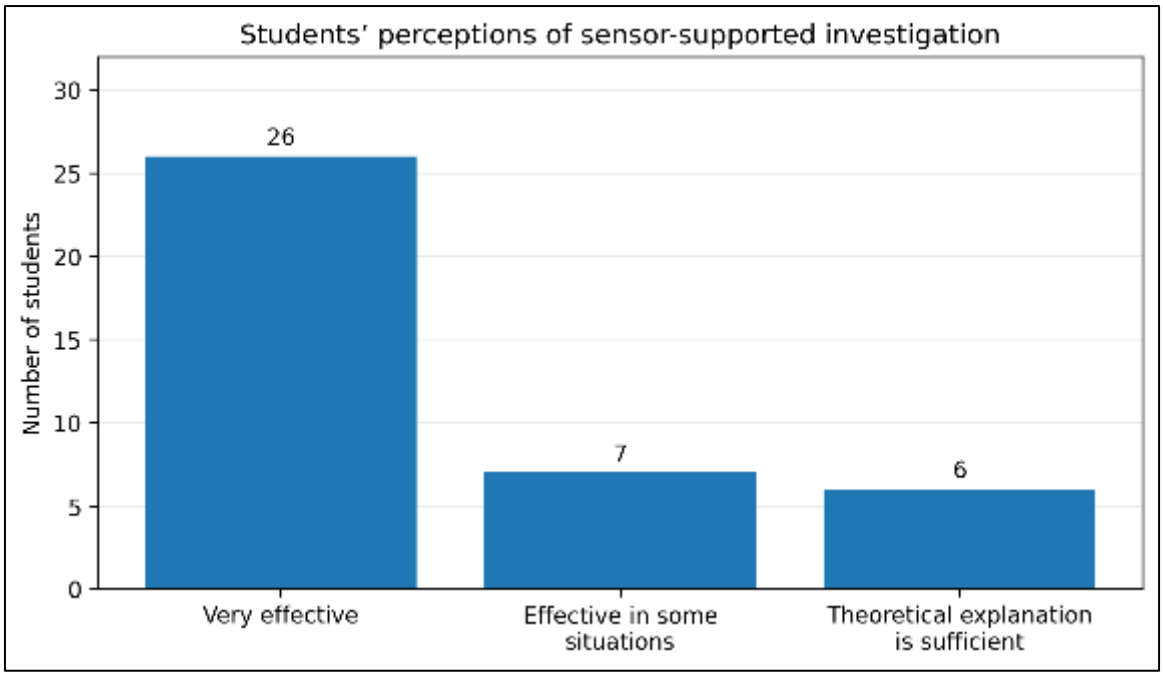



**Figure 2: Students' perceptions of the effectiveness of investigating physical phenomena with digital sensors.**

### 3.3 Perceived educational importance of Vernier experiments

The third figure in the source manuscript indicates that 26 students considered Vernier-supported experiments helpful for understanding learning material in greater depth, six reported that they helped to some extent, and seven indicated that they had no significant effect. These frequencies total 39 and are reproduced in Figure 3.

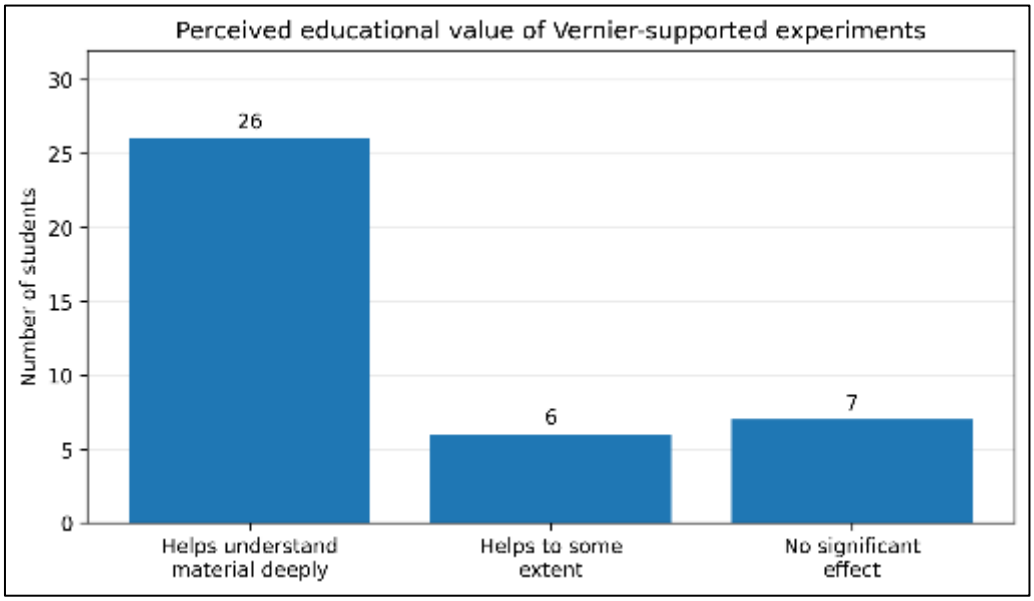



**Figure 3: Students' perceptions of the educational value of Vernier-supported experiments.**

### 3.4 Associations between questionnaire variables

The source manuscript included four contingency tables. Their observed frequencies are reproduced below. These tables are descriptive cross-tabulations; the small sample size and sparse expected counts require cautious interpretation.

**Table 1: Association between students' interest and perceived effectiveness**

| Interest level | Effective | Sometimes effective | Ineffective | Total |
|---|---|---|---|---|
| High | 25 | 3 | 1 | 29 |
| Moderate | 4 | 1 | 1 | 6 |
| Low | 1 | 2 | 1 | 4 |
| Total | 30 | 6 | 3 | 39 |

**Table 2: Association between students' interest and previous experience with sensors**

| Interest level | Used frequently | Used rarely | Never used | Total |
|---|---|---|---|---|
| High | 18 | 8 | 3 | 29 |
| Moderate | 2 | 2 | 2 | 6 |
| Low | 0 | 1 | 3 | 4 |
| Total | 20 | 11 | 8 | 39 |

**Table 3: Association between familiarity with Vernier sensors and students' interest**

| Familiarity level | High interest | Moderate interest | Low interest | Total |
|---|---|---|---|---|
| Know well | 9 | 1 | 0 | 10 |
| Have some understanding | 15 | 4 | 1 | 20 |
| Do not know | 5 | 1 | 3 | 9 |
| Total | 29 | 6 | 4 | 39 |

**Table 4: Association between perceived effectiveness and attitudes towards automated data collection**

| Perceived effectiveness | Very useful | Sometimes useful | Not necessary | Total |
|---|---|---|---|---|
| Effective | 26 | 3 | 1 | 30 |
| Sometimes effective | 3 | 2 | 1 | 6 |
| Ineffective | 1 | 1 | 1 | 3 |
| Total | 30 | 6 | 3 | 39 |

### 3.5 Reanalysis of the contingency tables

**Table 5: Results of the reanalysis of associations between questionnaire variables using the conditional Monte Carlo procedure**

| Comparison | Pearson $\chi^2$ | df | Monte Carlo p | Bonferroni-adjusted p |
|---|---|---|---|---|
| Interest × perceived effectiveness | 8.27 | 4 | 0.085 | 0.341 |
| Interest × previous experience | 10.89 | 4 | 0.022 | 0.086 |
| Sensor familiarity × interest | 7.57 | 4 | 0.111 | 0.443 |
| Perceived effectiveness × automated data | 8.06 | 4 | 0.088 | 0.352 |

The chi-square values and p-values reported in the original manuscript could not be reproduced from the displayed cell frequencies. The tables were therefore recalculated. Since expected frequencies were below five in several cells, the p-values below are conditional Monte Carlo estimates based on 500,000 random tables with fixed row and column totals. The four comparisons were treated as exploratory and adjusted using the Bonferroni method.

Before adjustment, the association between interest and previous experience with sensors reached the nominal 0.05 significance level (Monte Carlo $p = 0.022$). However, none of the four comparisons remained statistically significant after Bonferroni adjustment (all adjusted p-values > 0.05). Accordingly, the data do not support the original manuscript's statement that all four associations were statistically significant. These results should be verified against the original response-level dataset before publication.

### 3.6 Methodological example: investigating Ohm's law

The source manuscript describes a laboratory activity intended to investigate the relationship between electric current and voltage using Vernier current and voltage sensors. The activity is connected to Ohm's law, expressed as $I = U/R$, where I is electric current, U is voltage, and R is resistance. The stated purpose is to determine experimentally the relationship between current and voltage in an electrical circuit.

The activity can be organized in five instructional stages. First, students review the relevant theoretical relationship and formulate a prediction. Second, the teacher introduces the sensors and explains the measurement procedure and circuit arrangement. Third, students collect current and voltage measurements for the selected circuit conditions. Fourth, the data are organized in a table and represented graphically so that the relationship between the measured quantities can be examined. Fifth, students discuss the results, consider possible measurement uncertainties, and formulate a conclusion about the relationship described by Ohm's law.

The original manuscript lists a Vernier current sensor, a Vernier voltage sensor, resistors, a power supply, a breadboard, and a computer or tablet as the equipment. It does not include the actual measurement dataset or the graph produced during the activity. These results should be inserted if they are available; numerical readings must not be reconstructed or invented.

### 3.7 Limitations

The study has several limitations. First, the sample consisted of 39 students from one grade level at a single school, which limits the generalizability of the findings. Second, the reported results are primarily questionnaire responses and observations; no control group, pre-test/post-test comparison, or independently measured achievement outcome is documented. Third, the original chi-square results were inconsistent with the displayed contingency tables, and the reanalysis presented here is based only on the frequencies shown in the manuscript. Finally, one of the original graphs concerning students' familiarity with Vernier sensors appears to contain frequencies that sum to 38 rather than 39. These limitations mean that the findings should be interpreted as exploratory and descriptive.

## 4 CONCLUSION

This study examined the organization of school physics experiments using Vernier digital sensors and described the attitudes of 39 tenth-grade students towards sensor-supported laboratory activities. The item-level questionnaire results indicate that most participants expressed interest in using digital sensors and viewed their application in investigating physical phenomena positively.

The cross-tabulations provide descriptive information about the relationships among students' interest, previous experience, familiarity with sensors, and perceptions of automated data collection. Reanalysis using conditional Monte Carlo procedures showed that only the association between interest and previous experience reached the nominal 0.05 level; none of the four comparisons remained significant after adjustment for multiple testing. These findings do not establish that Vernier sensors caused an improvement in students' achievement.

The laboratory example based on Ohm's law illustrates a possible sequence for integrating digital measurement into physics teaching: theoretical preparation, sensor familiarization, data collection, graphical analysis, and evidence-based conclusion. Further studies should report the research context and procedures in full, include the complete questionnaire and raw anonymized data, and use appropriate comparison designs and validated measures of learning outcomes. Such work would provide a stronger basis for evaluating the contribution of Vernier digital sensors to physics education.

## STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

*Disclosure of conflict of interest*

The authors declare no conflicts of interest regarding this manuscript.

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