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DEVELOPMENT OF SCIENCE PROCESS SKILLS ASSESSMENT INSTRUMENTS IN ONLINE MAGNETIC FIELD LAB LABS USING REMOTE PHYSICS LABS

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Abstrak

Penelitian ini bertujuan untuk mengembangkan dan menguji kelayakan instrumen penilaian keterampilan proses sains (KPS) pada praktikum online medan magnet topik koil tunggal menggunakan Remote Physics Lab (R-PhyLab). Penelitian menggunakan metode Research and Development (R&D) dengan model 4D (Define, Design, Develop, Disseminate) yang dibatasi hingga tahap Develop. Instrumen disusun dalam 15 butir soal pilihan ganda yang mencakup lima aspek KPS: mengamati, memprediksi, mengukur, menafsirkan data, dan berkomunikasi ilmiah. Validasi isi oleh tiga ahli menggunakan formula Gregory menghasilkan tingkat kesesuaian 80%, dengan 12 butir soal dinyatakan valid dan 3 butir perlu revisi. Uji coba dilakukan pada dua kelompok siswa di MAN Insan Cendekia Paser. Hasil analisis menunjukkan seluruh soal berada pada kategori mudah (P > 0,70) dan reliabilitas instrumen berada pada kategori sedang (KR-20 = 0,46). Instrumen ini berimplikasi pada tersedianya alat ukur yang dapat membantu guru fisika mengidentifikasi keterampilan ilmiah siswa secara autentik dalam konteks praktikum daring. Ke depan, instrumen ini dapat diadaptasi untuk topik fisika lain atau dikembangkan dengan format penilaian yang lebih bervariasi guna mendukung pembelajaran berbasis deep learning pada fase memahami.

Kata kunci: Keterampilan Proses Sains, Remote Physics Lab, Medan Magnet, Instrumen Penilaian, Pengembangan Instrumen

Abstract

This study aims to develop and test the feasibility of a science process skills (SPS) assessment instrument in an online magnetic field practicum on the topic of single coils using Remote Physics Lab (R-PhyLab). The study used the Research and Development (R&D) method with a 4D model (Define, Design, Develop, Disseminate) limited to the Develop stage. The instrument was structured in 15 multiple-choice questions covering five aspects of SPS: observing, predicting, measuring, interpreting data, and communicating scientifically. Content validation by three experts using the Gregory formula resulted in an 80% suitability level, with 12 items declared valid and 3 items requiring revision. The trial was conducted on two groups of students at MAN Insan Cendekia Paser. The analysis results showed that all questions were in the easy category (P > 0.70) and the instrument reliability was in the moderate category (KR-20 = 0.46). This instrument has implications for the availability of measuring tools that can help physics teachers identify students' scientific skills authentically in the context of online practicums. In the future, this instrument can be adapted for other physics topics or developed with a more varied assessment format to support deep learning-based learning in the understanding phase.

Keywords: Science Process Skills, Remote Physics Lab, Magnetic Fields, Assessment Instruments, Instrument Development

INTRODUCTION

21st-century physics education emphasizes mastery of science process skills (SPS) as key abilities that reflect scientific working methods, such as formulating problems, designing experiments, analyzing data, and drawing conclusions.[1] KPS not only serves as a provision for understanding physics concepts in depth, but also becomes an important foundation in forming scientific mindsets and 21st-century skills such as critical thinking and problem solving.[2]

However, a number of studies show that Indonesian students' mastery of KPS is still relatively low.[3] The contributing factors include limited laboratory access, minimal meaningful practical activities, and the lack of assessment instruments capable of measuring KPS in a valid and contextual manner.[4]

In the digital era, innovations in educational technology have opened up opportunities for online practicals.[5] One potential innovation is the Remote Physics Lab (RPL), an internet-based remote physics laboratory that allows students to conduct real experiments without having to be physically present in the laboratory.[6] Previous research shows that the use of RPL can improve students' conceptual understanding, scientific thinking skills, and learning motivation.[7] However, there is no KPS assessment instrument that is specifically designed and valid for the context of RPL-based physics practicums.[8]

The single coil as a magnetic field practicum topic is one of the basic experiments that is relevant and rich in potential for measuring students' KPS, such as the ability to observe symptoms,

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[1] Kartika Sulistyani et al., "The Analysis of Effectiveness of Guided Inquiry Implementation to Improve Students' Science Process Skills," IJORER : International Journal of Recent Educational Research 3, no. 6 (2022): 672–687, https://doi.org/10.46245/ijorer.v3i6.258.

[2] Syahrial A, *Analisis Pembelajaran Fisika Terintegrasi Steam Untuk Melatih Keterampilan Abad 21 Dan Keterampilan Proses Sains Siswa Pada Implementasi Kurikulum Merdeka: A Review | Journal of Classroom Action Research*, December 28, 2024, https://jppipa.unram.ac.id/index.php/jcar/article/view/5932.

[3] Tri Aulia Mutia Rahma Guritno et al., "Pembelajaran Kimia melalui Model Pemecahan Masalah dan Inkuiri Terbimbing Ditinjau dari Keterampilan Proses Sains (KPS) Dasar dan Sikap Ilmiah Siswa," *INKUIRI: Jurnal Pendidikan IPA* 4, no. 2 (2015): 1–9, https://doi.org/10.20961/inkuiri.v4i2.9530.

[4] Walidatul Awaliyah and Sa'diatul Fuadiyah, "Pengembangan Instrumen Tes Keterampilan Proses Sains Pada Materi Biologi Sistem Regulasi Tumbuhan Kelas XI SMA," *Invention: Journal Research and Education Studies*, May 25, 2025, 263–74, https://doi.org/10.51178/invention.v6i1.2500.

[5] Fadhil Widhiprasetyo et al., "Pengaruh Motivasi Belajar, Minat Belajar, Kondisi Kelas Terhadap Hasil Belajar Kelas XII dalam Menempuh Program Keahlian Rekayasa Perangkat Lunak Pada Mata Pelajaran Pemrograman Website di SMKN 11 Malang," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer* 9, no. 7 (2025), https://j-ptiik.ub.ac.id/index.php/j-ptiik/article/view/15143.

[6] Ruben Heradio et al., "Virtual and Remote Labs in Education: A Bibliometric Analysis," *Computers & Education* 98 (July 2016): 14–38, https://doi.org/10.1016/j.compedu.2016.03.010.

[7] Febri Pramesthi and Riki Perdana, "Pengembangan Media Pembelajaran Topik Pengukuran Berbantuan 3D Application Scratch Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa," *Jurnal Penelitian Sains Dan Pendidikan (JPSP)* 5, no. 1 (2025): 118–33, https://doi.org/10.23971/jpsp.v5i1.9630.

[8] Melisa Puspita Sari et al., "Tinjauan Literatur: Studi terhadap Penggunaan Aplikasi Google SketchUp dalam Meningkatkan Motivasi Belajar Geometri Siswa," *Afore : Jurnal Pendidikan Matematika* 4, no. 1 (2025): 85–96, https://doi.org/10.57094/afore.v4i1.2900.

formulate hypotheses, control variables, measure, and interpret data. This practicum is also in accordance with the Understanding phase in the deep learning approach, which includes the development of essential, applicable knowledge, as well as values and characters, through contextual and meaningful scientific activities. Therefore, this study aims to develop an online practicum-based science process skills (SPS) assessment instrument using Remote Physics Lab on the topic of single coil magnetic fields.

This research is expected to contribute to the development of assessment instruments appropriate to the digital learning context, capable of comprehensively measuring student achievement (KPS), and supporting deep learning through authentic and meaningful experimental activities. Furthermore, the results of this development can serve as a reference for teachers and assessment developers integrating online laboratory technology into science learning evaluations.

Science Process Skills (SPS) are cognitive and psychomotor abilities used in scientific investigations, such as observation, experimentation, and drawing conclusions. They reflect how scientists work and form the basis of inquiry-based science learning and the development of 21st-century skills.[9]

The development of science process skills strengthens conceptual understanding, scientific attitudes, and in-depth learning through hands-on experience,[10] Science process skills are divided into two:

1. Basic science process skills with indicators: observing, classifying, measuring, interpreting data, communicating.
2. Integrated science process skills with indicators: identifying variables, formulating hypotheses, designing and controlling experiments, drawing conclusions.

Table 1. Aspects of Science Skills and Their Indicators

Aspect	Indicators (measurable behavior)
Observing (Observation)	Using the five senses/tools to observe; recording facts as they are; distinguishing qualitative vs. quantitative characteristics; making a list of findings.
Classifying	Grouping objects based on one/a combination of criteria; creating category labels; explaining the reasons for grouping; constructing a class hierarchy.

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[9] S. Syahrir, I. Yusri, and R. Handayani, "Effect of guided inquiry-based virtual laboratory on students' science process skills and attitudes," Indonesian Journal of Science Education 10, no. 2 (2021): 189–197, https://doi.org/10.15294/jpii.v10i2.29092.

[10] Kartika Sulistyani et al., "The Analysis Effectiveness of Guided Inquiry Implementation to Improve Students' Science Process Skills," *IJORER : International Journal of Recent Educational Research* 3, no. 6 (2022): 672–87, https://doi.org/10.46245/ijorer.v3i6.258.

Aspect	Indicators (measurable behavior)
Measure	Selecting the right measuring tool; reading the scale correctly; writing down SI units; calculating simple uncertainties.
Temporary Inference	Stating conjectures based on observational data; distinguishing between facts and interpretations; providing logical reasons for inferences.
Prediction	Make predictions based on data patterns/trends; state assumptions; compare predictions with actual results.
Communicate	Presenting data in tables/graphs/diagrams; writing short reports; explaining procedures and results orally; using appropriate scientific terms.
Using Tools & Materials Safely	Read safety symbols; follow SOPs; prepare, use, and tidy up tools correctly; record risks and their prevention.

This indicator is important in designing assessment instruments and inquiry learning strategies, and has been proven effective in improving students' understanding and scientific thinking skills.

Remote Physics Lab (RPL) is an online physics laboratory that allows users to access and control real-world experimental equipment over the internet. Unlike simulations, RPL still uses physical equipment, maintaining the authenticity of the experiments. Remote physics labs are now widely used in science education due to their relevance to the digital era. Remote physics labs support flexible, authentic, and inquiry-based learning.[11] The use of remote physics labs has been proven to develop science process skills such as designing experiments, analyzing data, and drawing conclusions.[12]

The advantages of remote physics labs include inclusive access, flexibility in time and location, ease of documentation, and operational efficiency. However, optimizing remote physics labs requires infrastructure support, training, and appropriate learning and assessment strategies.

A magnetic field is the region around a magnet or electric current where a magnetic force can be felt by charged particles. Symbolized by B and measured in Tesla (T), this field is a crucial component of electromagnetism and plays a role in various technological applications such as

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[11] Zahra, A., Khalid, S., & Iqbal, J., "Remote Laboratories: Future of Practical Science Education amid COVID-19 Pandemic.," *Education and Information Technologies* 26, no. 6 (2021): 7569–87.

[12] Megan Sauter et al., "Getting Real: The Authenticity of Remote Labs and Simulations for Science Learning," *Distance Education* 34, no. 1 (2013): 37–47, https://doi.org/10.1080/01587919.2013.770431.

electric motors and MRI. Magnetic fields affect moving charged particles through the Lorentz force, which is defined as:

$$\vec{F} = q\vec{v} \times \vec{B} \qquad \text{s (1)}$$

With $\vec{F}$is the magnetic force (N), q is the particle charge (C), $\vec{v}$is the particle velocity (m/s), and $\vec{B}$is the magnetic field (T).

The quantitative relationship between magnetic fields and electric currents is summarized in a mathematical expression known today as the Biot-Savart law, namely:

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{Id\vec{l}\times\vec{\tau}}{r^2} \qquad (2)$$

With $d\vec{B}$is the magnetic field element (Tesla), μ_0 is the vacuum permeability ($4\pi \times 10^{-7}$ T·m/A), I is the electric current (A), $d\vec{l}$is the element of wire length (m), $\vec{r}$is the unit vector from the wire element to the observation point, and r is the distance from the wire element to the observation point (m).

For the total field, integration along the wire is performed:

$$d\vec{B} = \frac{\mu_{0I}}{4\pi}\int\frac{d\vec{l}\times\vec{\tau}}{r^2} \qquad (3)$$

In physics educational applications, this law is particularly relevant for understanding how current in a wire produces a magnetic field, particularly in single-coil and Helmholtz coil configurations.

A single coil is a circular wire of radius R carrying a current I, producing a magnetic field along its axis. The observation point is at a distance x from the center of the loop. By the Biot-Savart law and the symmetry of the field, only the component of the field along the x-axis persists.

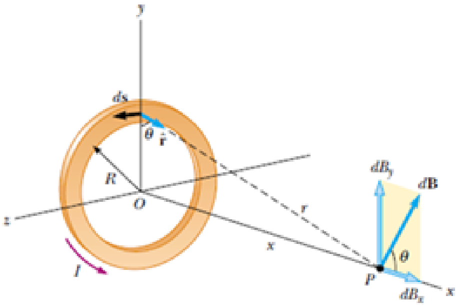

Figure 1. Geometry for calculating the magnetic field at point P located on the loop axis.

Magnetic field at point x on the coil axis:

$$B = \frac{\mu_0 I\, R^2}{2(R^2+z^2)^{3/2}} \qquad (4)$$

For the center point of the coil (z=0):

$$B = \frac{\mu_0 I}{2R} \qquad (5)$$

Understanding Phase in Deep Learning

The deep learning approach in education emphasizes the importance of meaningful learning, where students don't simply memorize information but are able to understand, relate, and apply knowledge in real-world contexts. One crucial stage in this approach is the understanding phase, which bridges the gap between basic information acquisition and the development of higher-order thinking skills.

According to the Ministry of Education, Culture, Research, and Technology, the understanding phase is part of the Independent Curriculum framework, designed to build essential and applicable knowledge, as well as values and character. In this phase, students are encouraged to explore the connections between scientific concepts and direct experience through exploratory and investigative activities, such as lab work and contextual problem-solving.

The understanding phase is highly relevant to the development of science process skills (SPS), as it encourages students to:

1. Observing phenomena systematically,
2. Predicting possible outcomes based on initial observations,
3. Measuring variables accurately,
4. Interpreting data from experimental results,
5. Communicate results logically and scientifically.

Thus, developing a KPS assessment instrument through online practicums like the Remote Physics Lab is highly aligned with the spirit of the understanding phase. This instrument not only measures cognitive achievement but also reveals how students construct knowledge through a holistic and contextual scientific process.

RESEARCH METHODS

This study uses a Research and Development (R&D) approach to develop a science process skills (SPS) assessment instrument in an online magnetic field practicum using a remote physics lab.[13] Nurmala et al. applied an R&D model to environmental practicums with comprehensive pedagogical, content, and language validation. The primary goal was to produce a product that was valid, practical, and impactful on deep learning.

Research Subjects

The sampling technique in this study used purposive sampling, which is the deliberate selection of samples based on certain characteristics. The sample consisted of 11 grade XII science students of MAN Insan Cendekia Paser who had studied magnetic fields and had experience using the Remote Physics Lab. This selection was based on the achievement of basic competencies and readiness to participate in online practicums. Each group carried out online practicums remotely using the Remote Physics Lab (R-PhyLab) on the topic of magnetic fields by a single coil.

Construct validation was conducted through expert judgment-based data triangulation, involving three physics education lecturers experienced in developing assessment instruments. The validators evaluated the appropriateness of the test items to the science process skill indicators, language appropriateness, and relevance to practical activities. The experts' suggestions and input were used to revise and refine the instrument before field trials.

Development Model

The model used in this research is the 4D model (Define, Design, Develop, Disseminate)[14], implemented only up to the Develop stage

1. Define: Literature study, curriculum analysis, teacher interviews.
2. Design: Preparation of indicators, grids, and question formats.
3. Develop: Expert validation (Aiken's V), student pilot test (Cohen's Kappa reliability).
4. Disseminate: (not implemented; recommended for further research).

Research Procedures

The research procedure flow in this case the development of science process skills instruments is depicted in the following flow chart:

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[13] I. Dewa Putu Subamia, “Pengembangan Perangkat Praktikum Berorientasi Lingkungan Penunjang Pembelajaran IPA SMP Sesuai Kurikulum 2013,” *JPI (Jurnal Pendidikan Indonesia)* 4, no. 2 (2015), https://doi.org/10.23887/jpi-undiksha.v4i2.6064.

[14] Bambang Hariyanto et al., “4D Model Learning Device Development Method of the Physical Geography Field Work Guidance Book,” *MATEC Web of Conferences* 372 (2022): 05008, https://doi.org/10.1051/matecconf/202237205008.

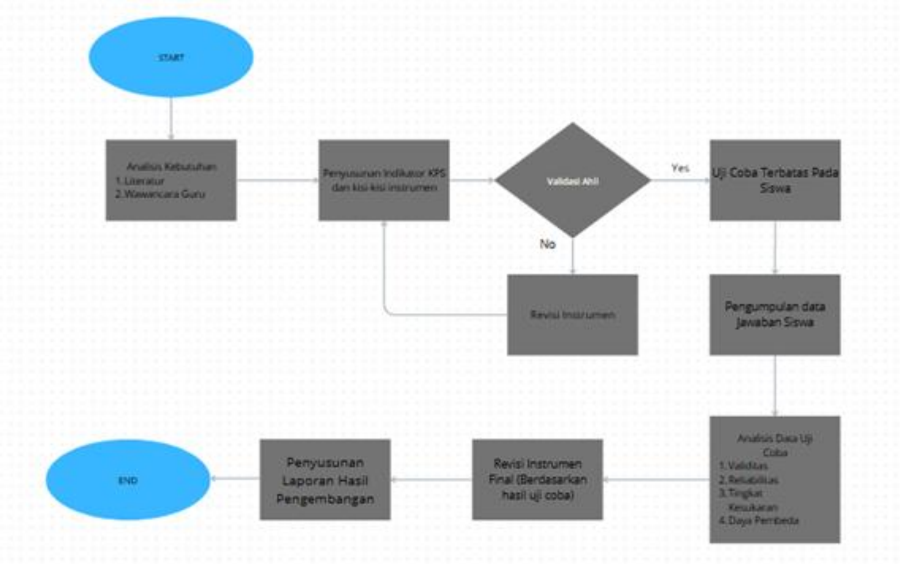

Figure 2. Flow Chart for Developing Science Process Skills Instruments

Instrument Validation

The instrument was validated by three expert validators, two physics education lecturers and one professional peer teacher. Validation was conducted on content, construct, and language aspects. Construct validation techniques were conducted using expert judgment to ensure that each item represented the KPS indicators conceptually and operationally. Validation results were calculated using the Gregory formula, and questions that did not meet the criteria were revised based on expert input.

Data collection technique

Data collected through:

1. Instrument expert validation sheet (using a scale of 1–5 per item)
2. Students' responses to the development results instruments after the implementation of the practicum
3. Documentation and field observation notes during online practicum

Data Analysis Techniques

1. Content validity was analyzed using Gregory's formula with the interpretation that a question item is declared valid if all four aspects (Aspects 1–4) have a value of 1.
2. The level of difficulty of the questions is calculated using the proportion formula (P), and is categorized as easy ($P > 0.70$), moderate ($0.30 \leq P \leq 0.70$), and difficult ($P < 0.30$).
3. The reliability of the instrument was tested using the KR-20 formula to determine the internal consistency between the test items.

RESULTS AND DISCUSSION

Define Stage

The Define stage aims to identify and define the basic needs underlying the development of the science process skills (SPS) instrument. In this stage, researchers conducted curriculum analysis, literature studies, and identified the characteristics of magnetic field practicums using the Remote Physics Lab. The analysis was conducted on relevant learning outcomes and basic physics competencies, particularly on the topic of magnetic fields and science process skills such as observing, predicting, measuring, interpreting data, and communicating scientifically.

Furthermore, researchers analyzed students' needs for digital lab-based assessment instruments capable of authentically representing scientific thinking processes. This phase resulted in initial instrument specifications, measurable SQI indicators, and a content validation needs map that will serve as the basis for subsequent development.

The define phase of this research resulted in the identification of the need for a KPS assessment instrument in the context of a magnetic field practicum based on a remote physics laboratory (Remote PhyLab). This finding is consistent with the principles of the initial stage of instrument development in the R&D approach, which emphasizes the need to map conceptual and empirical issues before designing an instrument prototype.[15] In the assessment instrument development model, needs analysis is considered a major determinant because incorrect definition of needs will result in an instrument that is neither conceptually nor instructionally relevant.[16]

In this study, learning outcomes related to the topic of magnetic fields and the Science Process Skills (SPS) domains such as observing, predicting, measuring, interpreting, and communicating data served as the basis for deriving indicators. The finding that students require instruments capable of authentically representing scientific thinking processes also reinforces the urgency of a process-based assessment paradigm rather than solely based on outcomes. This aligns with the view that science process skills cannot be measured through conventional paper-based assessments but must be measured through the context of scientific practice that allows students to perform scientific cognitive and psychomotor actions. This perspective emphasizes that SPS is contextual and only emerges when students are placed in observational or experimental situations that require inference.

The define stage in this study resulted in initial instrument specifications, measurable indicators, and a map of content validation needs. Theoretically, this reflects the fulfillment of the content-validity principle from the outset, as emphasized by Aiken that concept and content domain

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[15] Meredith D. Gall et al., *Educational Research: An Introduction (7th Edition)*, 7th ed. (Allyn & Bacon, 2003), http://gen.lib.rus.ec/book/index.php?md5=ebd06036ad1b9f55fedf09ca5cd0691d.

[16] John W. Creswell, *Research Design: Qualitative and Quantitative Approaches* (Sage Publications, Inc, 1994).

analysis must be conducted before items are written to prevent measurement bias. Thus, the results of the define stage not only fulfill the procedural requirements of the development model but also demonstrate the fulfillment of the theoretically and curricularly legitimate principles of assessment constructs.

Design Stage

The Design phase aims to develop an initial draft of the science process skills (SPS) instrument to be used in the Remote Physics Lab-based magnetic field practicum. In this phase, researchers formulated science process skills indicators based on five basic aspects: observing, predicting, measuring, interpreting data, and communicating. Each aspect was elaborated into operational indicators, which were then translated into contextual multiple-choice questions.

The instrument design was adapted to the digital lab activities available in R-PhyLab, particularly the observation of magnetic fields in a single coil. Each test item was designed to measure a specific indicator of science process skills, considering the principles of clarity of language content, contextual appropriateness, and pedagogical feasibility. Furthermore, a scoring framework and answer sheet format were prepared to support the analysis of difficulty and reliability in subsequent stages.

The design stage in the development of science process skills (SPS) instruments is the epistemological foundation in assessment-based research, because at this stage the structure of concepts, indicators, and measurement items are formulated deductively from the theoretical basis to a measurable instrument artifact that can be tested for reliability. The instrument design developed in the context of the Remote Physics Lab (R-PhyLab)-based magnetic field practicum does not exist in a vacuum, but reflects the demands of an authentic assessment paradigm that emphasizes the alignment between the objects being measured and the digital learning experiences that students actually experience.

The five basic aspects of SLP—observing, predicting, measuring, interpreting data, and communicating—are rooted in the fundamental literature on science education, which states that process skills are not only prerequisites for understanding concepts but also epistemic mechanisms by which students construct meaning from natural phenomena. In the context of virtual laboratory-based learning, mapping SLP indicators to digital practicum activities is necessary to ensure that the instrument does not measure pseudo-skills but rather the mental-cognitive processes that actually occur during remote experimental exploration.

The results of this stage are in the form of an initial draft of a science process skills instrument consisting of 15 multiple-choice questions that are ready to be tested for content validity by experts.

Table 2. Science Skills Instrument Grid

No	Aspek KPS	Indikator KPS	Nomor Soal	Tujuan Soal	Bentuk Soal	Jumlah Opsi	Konteks Eksperimen
1	Mengamati	Mengontrol variabel	1	Mengidentifikasi variabel yang harus dikontrol saat mengubah arus	PG	5	Pengaturan “Current of
2		Mengontrol variabel	2	Menentukan penyebab grafik simetris	PG	5	Data B vs d dari tabel/grafik
3		Mengontrol variabel	3	Menentukan variabel bebas dalam pengamatan efek arus	PG	5	Arus tetap, sensor
4	Memprediksi	Merumuskan hipotesis	4	Merumuskan hubungan antara B dan jarak berdasarkan tampilan grafik	PG	5	Grafik dari Remote Lab
5		Merumuskan hipotesis	5	Merumuskan pengaruh arus tinggi terhadap besar B	PG	5	Eksperimen I tinggi vs B
6		Merumuskan hipotesis	6	Menentukan hipotesis yang tidak sesuai dengan konsep medan	PG	5	Konsep $B \propto I$ dan $B \propto 1/r^2$
7	Mengukur	Melakukan eksperimen	7	Menentukan langkah awal sebelum eksperimen	PG	5	Menu “Current of coil” dan
8		Melakukan eksperimen	8	Menentukan tindakan untuk menyimpan data hasil pengukuran	PG	5	Tombol “Collect”
9		Melakukan eksperimen	9	Menjelaskan fungsi tombol “Reset” setelah eksperimen	PG	5	Tampilan tabel/grafik
10	Menafsirkan Data	Menginterpretasi data	10	Menjelaskan pola perubahan nilai B dari data tabel menuju titik pusat	PG	5	B vs d (dari -12 cm ke 0 cm)
11		Menginterpretasi data	11	Menafsirkan bentuk grafik medan magnet terhadap jarak sensor	PG	5	Kurva simetris
12		Menginterpretasi data	12	Menyimpulkan tren B saat sensor menjauh dari pusat	PG	5	Analisis tabel/grafik
13	Berkomunikasi	Menarik kesimpulan	13	Menyimpulkan hubungan d dan B secara umum dari hasil eksperimen	PG	5	Distribusi B simetris
14		Menarik kesimpulan	14	Menyimpulkan pengaruh arus terhadap medan magnet setelah	PG	5	Perbandingan data I = 0,3 A
15		Menarik kesimpulan	15	Menyimpulkan bentuk distribusi B dari sisi kiri ke kanan berdasarkan	PG	5	Analisis hasil tabel & grafik

Develop Stage

The Develop phase focused on developing and refining the KPS instrument based on expert validation and field trials. The initial instrument, consisting of 15 questions, was reviewed by three expert validators with expertise in physics education and instrument development.

1. Gregory Engineering Expert Validation Results

Content validation of the 15 questions on the science process skills instrument was conducted by involving three expert validators. Assessment was conducted on four aspects: indicator suitability, wording clarity, material relevance, and measurability. Scores were assigned on a scale of 1–4 and then converted according to guidelines: a score of 3–4 corresponds to a score of 1 (valid), while a score of 1–2 corresponds to a score of 0 (invalid). An item was declared valid if all validators gave a conversion score of 1 for all four aspects.

Based on the calculation results, out of a total of 15 questions, 12 questions (80%) were declared valid and 3 questions (20%) were invalid, namely items number 1, 7, and 8. This invalidity occurred because in one or more aspects, at least one validator gave a score below 3 before conversion. Invalid items were revised based on validator suggestions before the instrument was used in the study.

2. Level of Difficulty of Questions

The difficulty level of a question is measured using the difficulty index (p-value), which is the proportion of students who answer correctly. This index ranges from 0.0 to 1.0; the higher the value, the easier the question. According to educational standards, a range of 0.30–0.70 is considered ideal because it provides the most effective discrimination between students who understand and those who do not.[17]Questions with a p-value above 0.90 tend to be too easy and therefore less informative (The Scientist's Writing)."

The following graph presents a visualization of the level of difficulty of all instrument items:

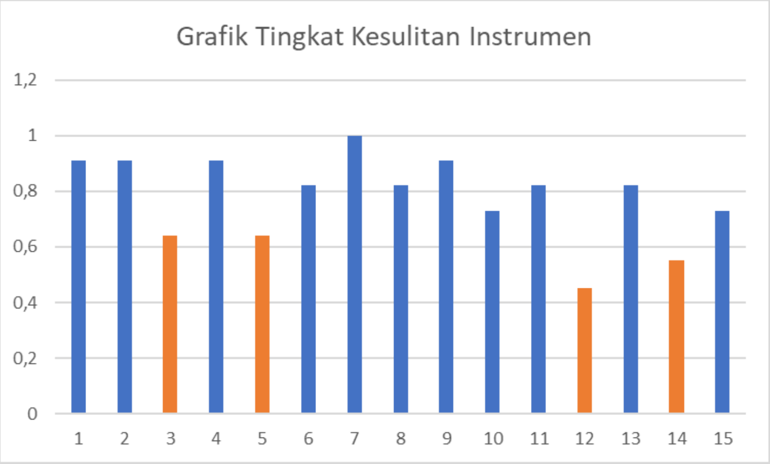

Figure 3. Science *Skill Instrument Difficulty Level Chart*

The calculation results show that most of the questions are in the easy category, with a proportion of more than 0.70. Four questions have a medium level of difficulty (meaning they are more difficult for students), namely questions 12 (0.45), 14 (0.55), and 3 & 5 (0.64). In contrast, question number 7 has the highest value, namely 1.00, which indicates that all students were able to answer the question correctly.

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[17] *Conducting Effective Item Analysis in Knowledge Tests • Food Safety Institute*, Research Methodology, December 29, 2023, https://foodsafety.institute/research-methodology/conducting-effective-item-analysis-knowledge-tests/.

3. Instrument Reliability

The Science Process Skills (SPS) assessment instrument, validated by three experts, was then piloted on 11 students. The students' answers were then analyzed to measure the instrument's reliability using the Kuder-Richardson 20 (KR-20) formula, as each question was multiple-choice with a dichotomous score (correct = 1, incorrect = 0). The equation used was:

$$\mathrm{KR}-20=\frac{k}{k-1}\left(1-\frac{\sum piqi}{\sigma^2}\right) \qquad (6)$$

Based on the results of the analysis using the KR-20 formula, a reliability value of 0.46 was obtained. Referring to the classification[18]This value is in the moderate category (0.41–0.60). This means that the developed science process skills (SPS) assessment instrument has sufficient internal consistency for the initial trial stage.

Table 3. Interpretation of Reliability Categories

Reliability Value	Category
0.00 – 0.20	Very low
0.21 – 0.40	Low
0.41 – 0.60	Currently
0.61 – 0.80	Tall
0.81 – 1.00	Very high

This "moderate" category indicates that most of the items are able to measure consistent aspects, although there is still room for improvement in the instrument's quality. Increasing reliability can be achieved through:

1. Improvement of questions with extreme difficulty index (too easy or too difficult),
2. Increasing the number of questions to strengthen consistency,
3. Implementation of the trial on a larger and more diverse group of participants.

Thus, this instrument is quite suitable for use as a measuring tool for science process skills, especially in the context of online practicum-based learning, but still requires further development to achieve high reliability.

Furthermore, several important findings emerged from the instrument trials. First, aspects of science process skills such as "controlling variables" and "conducting experiments"

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[18] J.P. Guilford, The Structure of Intellect (New York: McGraw-Hill, 1956).

tended to be easily understood by students, as evidenced by the high proportion of correct answers on questions measuring these two aspects.

This demonstrates that hands-on practical experience, even conducted online through Remote PhyLab, still positively impacts student understanding. Second, the aspects of "interpreting data" and "drawing conclusions" pose challenges. The low difficulty level of these questions indicates that students still struggle to analyze and relate experimental results to theoretical concepts. Therefore, these results can serve as a basis for further learning development that emphasizes strengthening students' analytical and inferential thinking skills.

These findings indicate that students' engagement in hands-on practicum experiences—even when conducted online through the use of Remote PhyLab—still makes a positive contribution to the construction of their conceptual understanding.[19]Direct interaction with physical phenomena through a digital interface can provide a sense of experimentation that is essential in science learning, because students not only receive information but also observe changes in variables and feel the consequences of experiments empirically.[20]However, higher-order thinking skills such as “interpreting data” and “drawing conclusions” appear to be cognitive bottlenecks; many students are unable to move beyond simply viewing data to interpreting, generalizing, and connecting it to existing theories.[21]

This condition confirms that remote labs, however powerful as a substitute for practical media, do not necessarily develop epistemic cognition without instructional strategies that are deliberately designed to elevate students to a higher cognitive realm, for example through scientific argumentation, reflective prompting, inferential scaffolding, or post-experimental conceptual reconstruction.[22]

From the pedagogical implications point of view,[23]These findings yield two main consequences: first, remote labs are proven to be a viable medium for science learning because they are capable of transferring phenomenological experiences to the online realm; second,

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[19] Victoria Borish et al., “Undergraduate Student Experiences in Remote Lab Courses during the COVID-19 Pandemic,” *Physical Review Physics Education Research* 18, no. 2 (2022): 020105, https://doi.org/10.1103/PhysRevPhysEducRes.18.020105.

[20] Herculano Henriques Chingui Chitungo et al., *Remote Labs in High School: A Case Study in Physics Teaching*, 7, no. 7 (2020), https://ijaers.com/detail/remote-labs-in-high-school-a-case-study-in-physics-teaching/.

[21] Suryadi et al., “Students’ Ability in Analysis and Interpretation of Data from Physics Investigation about Motion Kinematics,” *AIP Conference Proceedings* 2468, no. 1 (2022): 020013, https://doi.org/10.1063/5.0103041.

[22] Yasser H. Elawady and A. S. Tolba, “Educational Objectives Of Different Laboratory Types: A Comparative Study,” arXiv:0912.0932, preprint, arXiv, December 4, 2009, https://doi.org/10.48550/arXiv.0912.0932.

[23] Dimitri R. Dounas-Frazer and H. J. Lewandowski, “The Modeling Framework for Experimental Physics: Description, Development, and Applications,” *European Journal of Physics* 39, no. 6 (2018): 064005, https://doi.org/10.1088/1361-6404/aae3ce.

physics learning should not stop at experimental activities without an interpretative-justificatory phase, because experiments merely provide raw materials while interpretation provides scientific value.

Therefore, future learning design needs to orchestrate three layers: (1) empirical experience as a primary data source, (2) cognitive scaffolding to elevate students to the analytical-inferential realm, and (3) argumentative validation as a tester of the coherence of reasoning against theory.[24]This integration is expected to not only improve task performance, but transform the way students "think as scientists."

Finally, the practice of using Remote PhyLab in this experiment proves that virtual laboratories can be an innovative solution in implementing science process skills assessments effectively and efficiently, especially in limited space and time.

CONCLUSION

This research successfully developed an online practicum-based science process skills (SPS) assessment instrument on the topic of single coil magnetic fields using Remote Physics Lab with a 4D Research and Development (R&D) model approach (Define, Design, Develop, Disseminate) adapted to the Develop stage. The developed instrument contained 15 contextual multiple-choice questions covering five SPS aspects, namely observing, predicting, measuring, interpreting data, and communicating.

The results of content validation by three experts using the Gregory method showed that of the 15 science process skills instrument items validated by three experts in four assessment aspects, 12 items (80%) were declared valid and 3 items (20%) were invalid (numbers 1, 7, and 8). The invalid items were revised according to validator input before being used in the study.

The development of this instrument aligns with the understanding phase of the deep learning approach and the Independent Curriculum framework, which emphasizes essential and applicable knowledge, as well as values and character. Through online practicums based on the Remote Physics Lab, this instrument not only measures cognitive learning outcomes but also reveals students' scientific thinking processes in a holistic and contextual manner.

Implicationally, this instrument can be used by physics teachers to conduct authentic assessments in online practical learning, serve as a reference for the development of similar instruments in other physics topics, and contribute to improving the quality of assessment in the digital learning era.

However, this study is limited by its scope, which focused only on the topic of single-coil magnetic fields, the limited number of respondents, and the lack of in-depth construct validity

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[24] Dounas-Frazer and Lewandowski, "The Modeling Framework for Experimental Physics."

testing. Therefore, further research is recommended to expand the scope of the material, involve a more diverse sample, and integrate more comprehensive construct validity testing and reliability analysis.

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