https://doi.org/10.37640/jip.v16i2.2019 e-ISSN 2623-0380

# Virtual Laboratory-Based Inquiry Restoration: Anderson's Knowledge Dimension Assessment

Muh Tawil[1]*, Nurfitra Yanto[2]
[1]Department of Science Education, Universitas Negeri Makassar, Indonesia
[2]Department of Science Education, Universitas Negeri Makassar, Indonesia
muh.tawil@unm.ac.id*

**Abstract**

This study assesses the Virtual Laboratory-Based Inquiry Restoration (VLab-InR) model's effectiveness in enhancing students' factual and procedural knowledge. Developed as a virtual science lab alternative, especially useful during COVID-19 restrictions, the model structures science experiments in a digital environment. A quasi-experimental design with 42 students in two non-randomized groups, A and B, was employed. Pre- and post-assessments measured knowledge gains, and a questionnaire gauged student response. Data analysis using an independent t-test showed significant improvements, with a moderate normalized gain in both groups. Group A had a higher average increase than Group B. Students rated VLab-InR positively, with an approval average of 91.58%. Findings suggest VLab-InR effectively enhances factual and procedural knowledge and fosters critical thinking through virtual simulations, offering a practical solution for science learning in the digital age.

Keywords: Anderson, laboratorium virtual, inquiry restoration

Received: October 2, 2024 Revised: November 14, 2024 Accepted: November 21, 2024

**Article Identity:**

Tawil, M., & Yanto, N. (2024). Virtual Laboratory-Based Inquiry Restoration: Anderson's Knowledge Dimension Assessment, *Jurnal Ilmu Pendidikan (JIP) STKIP Kusuma Negara*, 16(2), 203-217.

## INTRODUCTION

Learning recovery is indispensable to face the challenges of the current information technology era. In this context, the knowledge dimension of Anderson, such as factual and procedural knowledge, plays an important role in supporting this development. This statement is in line with the opinion of Prisecaru (2016), which states that in the 21st century, the mastery of factual and procedural knowledge is needed to face global challenges.

During the COVID-19 pandemic, learning at school was carried out online, so students could not carry out offline experimental activities in the physics laboratory. In fact, this direct experiment activity is needed to deepen students' factual and procedural knowledge. The results of Elvanisi et al. (2018) research in Indonesia show that students' thinking skills are still low, especially in terms of factual and procedural knowledge at the secondary school level.

To overcome this problem, the implementation of the VLab-InR Model offers an effective solution. The VLab-InR model allows students to conduct virtual simulations of scientific experiments, helping them understand factual and procedural concepts that cannot be obtained through regular online learning. Gunawan et al. (2019) mentioned that computer simulation as a teaching medium is an important component in modern learning systems, especially in the context of science education. Through this model, students can practice factual knowledge, such as recognizing measuring instruments and their functions, as well as procedural knowledge, such as how to use tools, conducting experiments, creating tables and graphs, and displaying other science skills (Ladwig et al., 2012; Yustiana et al., 2018; Tapia, 2018; Vukic et al., 2020; Mills, 2022). Various studies show that virtual laboratories (VLab) are also able to improve student learning outcomes (Susantini, 2016; Luo, 2020).

Bloom's revised taxonomy, which includes factual knowledge, conceptual, procedural, and metacognitive dimensions, can be used as a guide in developing more complex cognitive processes (Ladwig et al., 2012; Yustiana et al., 2018; Tapia, 2018; Vukic et al., 2020; Mills, 2022). Factual knowledge helps students recognize and remember basic information that can be expressed orally or in writing (Zainuddin, 2010; Surif et al., 2012), while procedural knowledge includes the step-by-step skills necessary to understand the facts and scientific concepts studied. In line with that, Aini et al. (2021) emphasized that the mastery of factual knowledge by science and mathematics teachers is essential for teaching basic concepts, even though procedural knowledge is often overlooked.

Thus, both factual and procedural knowledge serve as a necessary foundation to support a comprehensive understanding of science experiments, as well as relevant in managing cognitive burdens that affect the learning and teaching process (Mazumder et al., 2019; Ladwig et al., 2012).

## Literature Review

The experimental results obtained will be the same as the results of the Physics Laboratory (Plab) Model. The virtual laboratory (VLab) overcomes some of the shortcomings of the VLab, namely: it is not possible for students to acquire thinking skills and information technology awareness. Physiologists believe that each type of laboratory has its own advantages, so the challenge is how to combine the two laboratories in a complementary way to achieve a learning effect (Abdulwahed & Nagy, 2011; Heradio et al., 2016), for example, researched by Wong et al., (2020) found that applying VLab and Microcomputer-Based Lab could help students understand the purpose of the experiment and increase student interest. A comparison of the results of these two groups suggested the integration of VLab and Microcomputer-Based Lab to facilitate student learning. Arista & Kuswanto, (2018); Haddade et al., (2023), combines a virtual physics laboratory with an android smartphone, the learning quality is very good.

VLab-InR Model, consists of five steps, i.e. problem identification, formulating hypotheses, data collection, data interpretation, conclusions (Raja, 2016). Factual experiment, i.e. the relationship between heat and changes in object temperature; the relationship between heat and changes in the state of matter, (3) the influence of salt on the melting point of ice (Ladwig et al., 2012; Yustiana et al., 2018; Tapia, 2018; Vukic et al., 2020; Mills, 2022). Virtual Laboratory (VLab) can improve learning outcomes (Susantini, 2016; Luo, 2020; Kartimi et al., 2023; Rihatno et al., 2023).

### *Factual Knowledge*

Consists of that introduced to a to problem. Elements reference, “symbol threads". Arise as part of the elements being discussed. Two types of factual knowledge, i.e.

terminology knowledge includes spesific names, detailed knowledge and particular places (Gani et al., 2011; Jiamu, 2012; Hong & Yang, 2018; Gamero et al., 2022; Tawil et al., 2023).

***Procedural Knowledge***

This knowledge can be new or adapted to spesific contexts. Indicators include subject-spesific expertise, algorithms, techniques, and methods (Jiamu, 2012; Hong & Yang, 2018; Eyina et al., 2019; Bintang et al., 2020; Giorgioa, 2020; Hermayawati, 2020; Klau, 2020; Zemljak and Virtič, 2022).

## RESEARCH METHOD

This research employed a between-group design using quasi-experiments pretest and posttest methods (Allen, 2017; Ramdani et al., 2021).

Table 1. Research Design (Ramdani et al., 2021)

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| A | $O_1$ | X | $O_2$ |
| B | $O_3$ | X | $O_4$ |

This study involved two group A (21 participants), group B (21 participants). The study was conducted to broaden understanding of the Vlab-InR model. Both Group A and Group B were given instructions using the VLab-InR model. The handling of the groups was adapted to include both asynchronous and synchronous online session. The effectiveness of the VLab-InR was determined based on the following criteria: (1) A statistically significant increase in factual and procedural scores is observed , (2) The mean factual and procedural scores fall within the moderate range , (3) The average normalized gain in factual and procedural scores differs significantly between Group A and Group B, (4) The effect size is categorized as moderate , (5) The percentage of student responses falls within the 'good' category.

***Implementation Model VLab-InR***

The implementation of the VLab-InR model consists of several steps:

1. **Introductory Activities**. Students respond to the delivery of learning objectives by preparing experimental virtual lab simulation software and worksheets, asking or proposing problem identification, and gathering information related to factual and procedural indicators.
2. **Core Activities**. Students create various experimental VLab simulations based on worksheets, observe variables in each investigation, formulated hypotheses about the relationship between the investigated variables, test hypotheses by conducting VLab simulation experiments, and create tables and graphs using observational data.
3. **Data Analysis Strengthening Activities**. Student analyze data from hypothesis testing by making explanations or arguments based on their findings; predicting, inferring and creating relationship equations between manipulated, response and control variables; identifying discrepancies with estabilshed

concepts, principles, and theories; and repeating experiments if the hypotheses are rejected.

4. **Evaluation Activities**. Students practice answering questions related to factual and procedural indicators online using google forms and prepare for discussion.

***Validasi dan Reliabilitas Instrument***

The factual instrument consists of 20 items, while the procedural instrument includes 10 items. Both test have a score range of 0-1. Additionally, a response questionnaire comprising 6 items was utilized. The two instruments were validated by three physics education experts. Validation analysis was performed using Gregory method (Arlini et al., 2017) as shown in Table 2. To calculate the internal consistency coefficient value (internal validation) equation (1) was used, and the category determination is presented in Table 3. The validation results indicate that the factual dan procedural test, as well as the response questionnaire, each have an internal validation value greater than 0.8, which falls into the high category. Therefore, these instruments are deemed suitable for use in this study.

Table 2. Gregory's validation analysis tabulation

| | Expert Assessment | |
|---|---|---|
| | Weak Relevance (Score 1 or 2) | Strong Relevance (Score 3 or 4) |
| Assessment is worth 1 or 2 | A | B |
| Assessment is worth 1 or 2 | C | D |

$$\text{Internal Consistency Coefficient (Internal validation)} = \frac{D}{A + B + C + D} \quad (1)$$

If both experts assign weak relevance, it is classified as A. When the first expert assigns strong relevance and the second expert assigns weak relevance, it is classified as B. If the first expert assigns weak relevance and the second expert assigns strong relevance, it is classified as C. Finally, if both experts assign strong relevance, it is classified as D.

Table 3. Validation category (Arlini et al., 2017)

| Interval | Category |
|---|---|
| > 0.8 | High |
| 0.4-0.8 | Medium |
| <0.4 | Low |

Reliability analysis of factual, procedural tests and response questionnaires was conducted to calculate the percentage of agreements between the two raters whose data was binary (i.e.,“yes” or “no”). The formula used is Formula (2) as described by Fuadi et al. (2015). The results of the reliability analysis were as follows: 100% for the factual and procedural tests; and 99% for the response questionnaires. Both results are above the lower limit which is greater than the lower limit of the reliability coefficient (0.75), indicating that all research instruments are reliable.

$$\text{Percentageof Agrrement} = \frac{\text{Agreement}}{\text{Disagreement} - \text{Agreement}} \text{x}100\% \quad (2)$$

***VLab-InR Model Effectiveness***

The VLab-InR model increases student factual and procedural understanding through the use of questions. The factual component includes the following indicators: (1) terminology knowledge encompasses spesific names, (2) detailed knowledge pertains to spesific places (Gani et.al., 2011; Jiamu, 2012; Hong & Yang, 2018; Gamero et al., 2022). For procedural knowledge: (1) subject-specific expertise and algorithms, (2) subject-specific techniques and methods, (3) investigation procedures (Jiamu, 2012; Hong & Yang, 2018; Eyina et.al., 2019; Bintang et.al., 2020; Giorgioa, 2020; Hermayawati, 2020; Klau, 2020). The scores obtained from the learning process are used to determine categories as shown in Table 4 (Lestari et al., 2021).

$$n-g=\frac{x_m-x_n}{100-x_n} \quad (3)$$

The normalized gain (g) is calculated, where Xm represents the post-test score and Xn represents the pre-test score.

Table 4. The normalized gain categories

| interval | category |
|---|---|
| g >0.7 | high |
| 0.3 ≤ g ≤ 0.7 | medium |
| g < 0.3 | low |

To conduct important analyses, the implementation of the VLab-InR Model and independent sample tests were carried out. Afterward, statistical calculations were performed using formula (4) and Formula (5) (Lestari et al., 2021).

$$\text{Effect size} = \frac{meanofposttestscore-meanofpretestscore}{standarddeviation} \quad (4)$$

Table 5. The Effect Size Categories (Lestari et al., 2021)

| Interval | Category |
|---|---|
| 0 – 0.20 | weak effect |
| 0.21 – 0.50 | modest effect |
| 0.51 – 1.00 | moderate effect |
| > 1.00 | strong effect |

Application of the VLab-InR Model questionnaire. Were. Analysis of formula (5) is used.

$$P=\frac{\sum K}{\sum N}x100\% \quad (5)$$

P represents the percentage of student responses, ∑K is the total score achieved by students, and ∑N is the highest score achieved by students.

Table 6. The Category of Students percentage response (Lestari et al., 2021)

| Interval | category |
|---|---|
| 81 - 100 | very good |
| 61 - 80 | good |
| 41 - 60 | adequate |
| 21 - 40 | not good |
| 0 - 20 | bad |

The VLab-InR Model encompasses the following key aspects: (1) significant increase in factual and procedural score; (2) Moderate average factual and procedural normalized gain score; (3) Mean factual and procedural normalized gain score between Group A and Group B, (4) Moderate effect size; (5) High percentage of positive responses.

## RESULTS AND DISCUSSION

The VLab-InR Model is a learning restoration approach that can enhance student factual and procedural knowledge. The model comprises five phases: (1) identification of problems, (2) construct hypotheses, (3) Data collection, (4) Analysis and interpretation of results, (5) repetition. Factual tests on group A and group B are shown in the Table 7 and Table 8.

Table 7. Tests of Normality Factual

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Factual | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| Pretest | 0.140 | 21 | 0.200 | 0.917 | 21 | 0.076 |
| Posttest | 0.145 | 21 | 0.200 | 0.960 | 21 | 0.507 |
| normalized gain | 0.100 | 21 | 0.200 | 0.972 | 21 | 0.785 |

In Table 7, the significance values for the pretest are 0.076, for posttest are 0.507, and for normalized gain are 0.765. These results indicate that the pretest, posttest, and normalized gain scores exhibit a normal distribution.

Table 8. Tests of Normality Factual

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Factual | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| Pretest | 0.138 | 21 | 0.200 | 0.955 | 21 | 0.420 |
| Posttest | 0.181 | 21 | 0.071 | 0.962 | 21 | 0.548 |
| normalized gain | 0.105 | 21 | 0.200 | 0.972 | 21 | 0.770 |

In Table 8, the significance values for the pretest are 0.420, for the posttest are 0.548, and for the normalized gain are 0.770. These results indicate a normal distribution for the pretest, posttest, and normalized gain score. Procedural tests on Group A and Group B are shown in Tables 9 and 10.

Table 9. Tests of Normality Procedural

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Procedural | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| Pretest | 0.156 | 21 | 0.200 | 0.950 | 21 | 0.342 |
| Posttest | 0.126 | 21 | 0.200 | 0.929 | 21 | 0.129 |
| N-gain | 0.140 | 21 | 0.083 | 0.867 | 21 | 0.090 |

In Table 9, the significance values for the pretest are 0.342, for the posttest are 0.129, and for the normalized N-gain are 0.090. These results indicate a normal distribution for the pretest, posttest, and normalized N-gain scores.

Table 10. Tests of Normality Procedural

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Procedural | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| Pretest | 0.138 | 21 | 0.200 | 0.950 | 21 | 0.340 |
| Posttest | 0.126 | 21 | 0.200 | 0.929 | 21 | 0.129 |
| normalized gain | 0.124 | 21 | 0.131 | 0.834 | 21 | 0.132 |

In Table 10, the significance values for the pretest are 0.340, for the posttest are 0.129, and for the normalized gain are 0.132. These results indicate a normal distribution for the pretest, posttest, and normalized gain scores.

The normalized gain normality test of students factual scores for Group A and Group B is shown in Table 11.

Table 11. Test of Normality

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Group | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| A | 0.100 | 21 | 0.200 | 0.972 | 21 | 0.785 |
| B | 0.105 | 21 | 0.200 | 0.972 | 21 | 0.770 |

In Table 11, the significance values for Group A and Group B normalized gain data are 0.785 and 0.770, respectively. These results indicate the both Group A and Group B exhibit a normal distribution.

The normalized gain normality test of students procedural scores for Group A and Group B is shown in Table 12.

Table 12. Tests of Normality

| | Kolmogorov-Smirnov | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| Group | Statistic | $df_1$ | Sig. | Statistic | $df_2$ | Sig. |
| A | 0.122 | 21 | 0.053 | 0.867 | 21 | 0.079 |
| B | 0.129 | 21 | 0.063 | 0.834 | 21 | 0.072 |

In Table 12, the significance values for the normalized gain data are 0.079 for Group A and 0.072 for Group B, respectively. These results indicate the both Group

A and Group B exxhibit a normal distribution. The homogeneity test of students factual and procedural normalized gain is shown in Table 13.

Table 13. Homogeneous test of variance

| | N | F | Sig. |
|---|---|---|---|
| Factual | 21 | 0.661 | 0.130 |
| Procedural | 21 | 0.116 | 0.527 |

In Table 13, the significance value for the factual and procedural normalized gain data is above 0.05. These results indicate that the two samples are homogeneous.

The effectiveness of the VLab-InR Model was evaluated using students factual and procedural test by applying VLab-InR Model before and after its implementation. this evaluation included pretest, posttest, normalized gain scores of students applying the VLab-InR Model in Group A and Group B.

Table 14. Average Factual Score

| | Group | |
|---|---|---|
| | A | B |
| Pretest | 30.90 | 36.52 |
| Posttest | 90.33 | 69.95 |
| normalized gain | 0.53 | 0.52 |

Table 14, show the value the student's in applying the VLab-InR Model in group A and group B. This student’s factual knowledge scores after implementing VLab-InR Model, in the a for group A and group B.

Table 15. Test of Paired

| Pretest-Posttest | Group | N | Mean | S | df | t | Sig. (p)* |
|---|---|---|---|---|---|---|---|
| | A | 21 | -40.42 | 19.11 | 20 | -9.69 | .000 |
| | B | 21 | -33.2 | 14.12 | 20 | -10.84 | .000 |

*p =.05

Tabel 15 show the students performance in applying the VLab-InR Model for Group A and Group B, including the significant (p) values for pretest and posttest scores, as well as the teacher skill scores in applying the VLab-InR Model for both groups. The average procedural scores for Group A and Group B are presented in Table 16.

Table 16. Average Procedural core

| | Average Score | |
|---|---|---|
| | Group A | Group B |
| Pretest | 61.61 | 61.63 |
| Posttest | 75.57 | 75.57 |
| normalized gain | 0.31 | 0.32 |

Table 16 show the scores the student's in applying the VLab-InR Model in Group A and Group B. These scores represent the students procedural knowledge after the implementing of the VLab-InR Model fot both groups.

Table 17. Test of Paired

| Pretest-Posttest | Group | N | Mean | S | df | T | Sig. (p)* |
|---|---|---|---|---|---|---|---|
| | A | 21 | -10.95 | 10.53 | 20 | -4.76 | .000 |
| | B | 21 | -11.23 | 10.50 | 20 | -4.90 | .000 |

*p =.05

Table 17 shows the students performance in applying the VLab-InR Model for Group A and Group B, including the significance (p) value for pretest and posttest scores, as well as the teacher skill scores in applying the VLab-InR Model for both groups.

The results of the independent samples t-test of students average normalized gain scores in factual knowledge for Group A and Group B are presented in Table 18.

Table 18. Test of Independent Samples

| | $\alpha$ | significant value |
|---|---|---|
| not | 0.05 | 0.421 |
| Equal variance not assumed | 0.05 | 0.421 |

The results of the independent Samples t-test for the students average normalized gain scores in procedural knowledge for Group A and Group B are presented in Table 19.

Table 19. Test of Independent Samples

| | $\alpha$ | significant value |
|---|---|---|
| not | 0.05 | 0.346 |
| Equal variance not assumed | 0.05 | 0.347 |

The results determining the effect size of the VLab-InR Model are presented in Table 20.

Table 20. Test of Effect Size

| Effect Size | | | | |
|---|---|---|---|---|
| Group | Factual | Category | Procedural | Category |
| A | 2.76 | strong effect | 0.90 | moderate effect |
| B | 1.24 | strong effect | 0.67 | moderate effect |

Table 20 shows the effect size values for students factual knowledge in applying the VLab-InR Model in Group A and Group B, which are 2.76 and 1.27, respectively, categorized as strong effects. The effect size values for students procedural knowledge in applying the VLab-InR Model in Group A and Group B are 0.90 and 0.67, respectively, categorized as moderate effects. These results fulfill the requirements for the effectiveness of the VLab-InR Model based on the data and are a key finding of this research.

The results of students responses to the VLab-InR Model are presented in Table 22 with an average response score of 91.58%.

Table 22. The Results of Student Response

| No. | Statement | Percentage (%) | Category |
|---|---|---|---|
| 1 | VLab-InR Model Instructions are very interesting and new | 94.22 | Very good |
| 2 | VLab-InR Model material is very interesting and new | 92.56 | Very good |
| 3 | New attractive VLab-InR Model worksheets | 90.33 | Very good |
| 4 | The learning atmosphere in the VLab-InR Model is fun | 90.34 | Very good |
| 5 | After learning activities using the VLab-InR Model, the factual is increasing | 90.33 | Very good |
| 6 | After learning activities using the VLab-InR Model, the procedural is getting better | 91.67 | Very good |
| | Average | 91.58 | Very good |

Student activities in the VLab-InR Model include developing knowledge of thermology, specific elements, new scientific information, discovering concepts, principles, scientific theories, as well as thinking and collaborating, observing, measuring, conducting scientific investigations, interpreting data, and drawing conclusions. Giorgioa et al. (2020) argue that factual and procedural indicators can be effectively trained during the learning process.

The application of the VLab-InR Model demonstrated its ability to enhance both factual and procedural knowledge. This finding validates the VLab-InR Model effectiveness in fostering these competencies. Wong et al. (2020) found that the VLab-InR Model can increases student interest and improves learning outcomes.

Form Table 7-11, the results of the normality tests for factual and procedural data indicated that all samples are normally distributed. Table 16 reveals a significant value of 0.000, smaller than the threshold of 0.05, indicating a significant improvement in factual knowledge. The t-values of -9.69 and -10.84 confirm this. In Table 18, the t-values of -4.76 and -4.90 demonstrate that posttest scores for procedural knowledge are significantly greater than pretest scores. These findings highlight the increase in both factual and procedural knowledge after applying the VLab-InR Model, supporting its effectiveness in training these indicators. This finding indicates that the VLab-InR Model can be applied to train factual and procedural indicators.

Surif et al, 2012; Vallance et al, 2017; Tomljenović, 2020, assert that procedural and conceptual knowledge can be cultivated through learning activities. Virtual laboratories offer an interactive platform for teachers and students, especially in the context of 21st century technology advancements. Factual and procedural knowledge represent higher-order thinking skills that can be nurtured both in the classroom and science laboratories (Miller & Hudson, 2017; Nicole et al. al., 2017; Macias-Romero, 2018; Fitria, 2019; Lenz, 2019;Eyina et al, 2019; Blažević1 and Klein, 2022)

The effect size analysis for factual knowledge in Groups A and B yielded value of 2.70 and 1.24 categorized strong effects. For procedural knowledge, the effect size were 0.90 and 0.67 categorized as moderate effects, fulfilling the effectiveness criteria for the VLab-InR Model. Active student participation in virtual laboratory activities fosters creativity through inquiry-based (Tanase, 2011; Nicole, 2017; Rukminingsih, 2020; Svensson, 2021; Pushenko, 2021).

Computer-generated virtual reality simulations provide interactive results, helping students develop factual and procedural knowledge (Vallance et al., 2017; Untu et al., 2020; VuČić et al., 2020; Blažević & Klein, 2022). The percentage of positive student responses to the VLab-InR Model reached 90.22%. This indicates that learning activities encourage active students engagement in task such as information through observation, problem-solving, hypothesis testing, data processing, data presentation, analysis, reasoning, drawing conclusions, creating equations, and reflection on investigations (Vallance, 2017; Saks, 2021; Son, 2022; Widiana et al., 2020; Wuryaningrum et al., 2020; Yilmaz & Yalçin, 2022).

Students using VLab-InR Model conduct experiments virtually via the Physics Education Technology (PhET) simulation Website http://phet.colorado.edu, (2021). Prihatiningtyas et al. (2013), Sinulingga et al. (2016), Saputra et al. (2020), Hung & Tsai, (2020) suggest that applying PhET simulations in science education enhances student engagment and learning outcomes. There is a strong correlation between virtual experimental activities and the development of higher-order thinking skills (Herga et al., 2015; Penn & Mavuru, 2020; Tawil et al., 2023). Thus, the VLab-InR Model significantly improves both factual and procedural knowledge.

## CONCLUSION

The VLab-InR Model has been proven effective in enhancing students factual, procedural knowledge. This effectiveness is demonstrated by a significant increase in factual and procedural knowledge ($\alpha$ = .05), the average normalized gain for factual knowledge in groups A and B was -9.69 and -10.84, respectively. Similarly, the average normalized gain for procedural knowledge in groups A and B was -4.76 and -4.90 respectively.

The effect size for factual knowledge in groups A and B was 2.76 and 1.24, respectively, categorizing both as having a of strong effect. For procedural knowledge, the effect sizes were 0.90 and 0.67 for groups A and B respectively, falling into the moderate effect category. These results indicate that both groups meet the effectiveness criteria for the VLab-InR Model.

Additionally, the average student response to the VLab-InR Model was 91.58%, highlighting its success as an alternative approach for virtual science practices. The model effectively trains students in factual and procedural knowledge , making it a valuable tool for higher education settings.

## REFERENCES


Abdulwahed, M., and Nagy, Z. K. (2011). The TriLab, a novel ICT based triple access mode laboratory education model. *Computers & Education*, *56*(1), 262-274.https://doi.org/10.1016/j.compedu.2010.07.023

Allen, M. (2017). *One-Group Pretest–Posttest Design*. The SAGE Encyclopedia of Communication Research Methods.

Arista, F. S., and Kuswanto, H. (2018). Virtual physics laboratory application based on the android smartphone to improve learning independence and conceptual understanding. *International Journal ofInstruction*, *11*(1), 1-16.https://doi.org/10.12973/iji.2018.1111

Arlini, H., Humairah, N., and Sartika, D. (2017). Penerapan model pembelajaran kooperatif tipe think pair share dengan teknik advance organizer (Implementation of the think pair share type Cooperative Learning Model with the Advance Organizer Technique). *Jurnal Saintifik*, *3*(2),182-189. https://doi.org/10.31605/saintifik.v3i2.163.

Aşkın, Ö. E., and Öz, E. (2020). Cross-National Comparisons Of Students' Science Success Based On Gender Variability: Evidence From Timss. *Journal Of Baltic Science Education*, *19* (2), 186-200. https://dx.doi.org/10.33225/jbse/20.19.186

Ayfer, M., and Şeşen, B, C. (2016). Impact of virtual chemistry laboratory instruction on pre-service science teachers' scientific process skills. In *SHS Web of Conferences*, *26*, 01088. https://doi.org/10.1051/shsconf/20162601088

Blažević1, I., and Klein, N. (2022). Digital media and internet safety among primary school students during the covid-19 pandemic.*Revija Za Elementarno IzobraževanjeJournal Of Elementary Education*, *15*(2), 127–144 https://doi.org/10.18690/rei.15.2.127-144.2022

Brown, B. A., Boda, P., Lemmi, C., & Monroe, X. (2019). Moving Culturally

Eyina, E. N., Moko, A., & Onuodu, F. E. (2019). A comparative study of procedural and factual knowledge representation and reasoning. *International Journal of Research and Innovation in Applied Science* (IJRIAS), *4*(12), 78-81

Elvanisi, A., Hidayat, S., and Fadillah, E. N. (2018).Analisis keterampilan proses sains siswa sekolah menengah Atas (Science Process Skills Analysis of High School Students).*Jurnal Inovasi Pendidikan IPA*, *4*(2), 245-252. https://doi.org/10.21831/jipi.v4i2.21426

Fuadi, S, T., & Lestari, W. (2015).Pengembangan instrument penilaian psikomotor pembelajaran pamateri tumbuhan hijau berbasis starter experiment approach berwawasan konservasi. *Journal of Educational Research and Evaluation (JERE.*, *4*(1), 1-11.

Gunawan, Harjono, A., Hermansyah, and Lovy Herayanti. (2019). Guided inquiry model through virtual laboratory to enhance students' science process skills on heat concept.*Cakrawala Pendidikan*, *38*, (2), 259-268.

Gupta, S. (2015). Influence of students' gender and stream of study on scientific attitude and attitudes towards science. *International Journal of Research-Granthaalayah*, *3*(12), 187-194. https://doi.org/10.29121/granthaalayah.v3.i12.2015.2905

Haddade, H., Nur, A., Mustami, M. K. & Achruh, A. (2023). Technology-based learning strategies in Digital Madrasah Program. Cypriot Journal on Educational Sciences. 18(1), 55-70 https://doi.org/10.18844/cjes.v18i1.8179

Heradio, R., Torre, D, L., Galan, D., Cabrerizo, F. J., Herrera-Viedma, E., and Dormido, S. (2016). Virtual and remote labs in education: A bibliometric analysis. *Computers & Educatio, 98*, 14-38.

Herga, N. R., Glažar, S. A., and Dinevski, D. (2015). Dynamic visualization in the virtual laboratory enhances the fundamental understanding Of chemical concepts. *Journal of Baltic Science Education*, *14*(3), 351-365https://doi.org/ 10.33225/ jbse/ 15.14.351

http://phet.colorado.edu. (2021). Physics Education Technology (PhET). Universitas Colorado di Boulder, Amerika. http://indieschool80.blogspot.com/2019/02/phet-media-pembelajaran-simulasi.html

Hung, J. F., and Tsai, C. Y. (2020).The Effects of a virtual laboratory and metacognitive scaffolding on students' data modeling competences. *Journal of Baltic Science Education, 19*(6), 923-939. https://doi.org/ 10.33225/ jbse/ 20.19.923

Ibrahim, D. (2011). Engineering simulation with MATLAB: improving teaching and learning effectiveness. *Procedia Computer Science, 3*, 853-858. https://doi.org/10.1016/j.procs.2010.12.140

Kartimi, K., Riyanto, O. R. & Winarso, W. (2023). Digital competence of science teachers in terms of gender, length of work, and school levels of teaching. *Cypriot Journal of Educational Science,18*(1), 31-42. https://doi.org/10.18844/cjes.v18i1.7779

Lestari, T., Supardi, Z. A., and Jatmiko, B. (2021). Virtual grouproom critical thinking as an alternative teaching model to improve students' critical thinking skills in pandemic coronavirus disease era. *European Journal of Educational Research, 10*(4), 2003-2015. https://doi.org/10.12973/eu-jer.10.4.2003

Luo, M., Wang, Z., Sun, D., Wan, Z. H., and Zhu, L. (2020). Evaluating scientific reasoning ability: the design and validation of an assessment with a focus on reasoning and the use of Evidence. *Journal of Baltic Science Education*, *19*(2), 261-275. https://doi.org/ 10.33225/ jbse/ 20.19.261.

Mnguni, L., and Mokiwa, H. (2020). The integration of online teaching and learning in stem education as a response to the COVID-19 pandemic. *Journal of Baltic Science Education*, *19*(6A). https://doi.org/10.33225/jbse/20.19.1040

Nugrahani, M. (2018). Pembelajaran fisika dengan pendekatan saintifik menggunakan metode eksperimen dan metode proyek ditinjau dari kreatifitas dan kemampuan pemecahan masalah pada siswa kelas XI SMAN 2 Surakarta tahun pelajaran 2015-2016 (Learning physics with a scientific approach using the experimental method and the project method in terms of creativity and problem-solving abilities in group XI students of SMAN 2 Surakarta in the 2015-2016 school year). *Jurnal Pendidikan Konvergensi Edisi*, *25*(4), 49-68. http://jurnal.fkip.uns.ac.id/index.php/sains

OECD (2019), *PISA 2018 results* (volume I): *What students know and can do*, PISA, OECD Publishing, Paris. https://doi.org/10.1787/5f07c754-en

OECD. (2019), *PISA 2018 results* (volume II): *Where all students can succeed*, PISA, OECD Publishing, Paris.https://doi.org/10.1787/b5fd1b8f-en

OECD. (2019), *PISA 2018 results* (volume III): *What school life means for students' lives*, PISA, OECD Publishing, Paris.https://doi.org/10.1787/acd78851-en

OECD. (2021). *Education at a glance* 2021 OECD INDICATORS. https://doi.org/10.1787/b35a14e5-en

Penn, M., and Mavuru, L. (2020). Assessing pre-Service teachers' reception and attitudes towards virtual laboratory experiments in life sciences. *Journal of Baltic science education, 19*(6A), 1092-1https://doi.org/10.33225/jbse/20.19.1092

Priyayi, D. F., Airlanda, G. S., and Banjarnaroh, D. R. V., (2020). Students' scientific attitude during the implementation of innovative green garden-based education. *JPBI (Jurnal Pendidikan Biologi Indonesia), 6*(2), 293-304. https://doi.org/10.22219/jpbi.v6i2.11402

Prihatiningtyas, S., Praswoto, T., and Jatmiko, B. (2013). Implementasi simulasi PheT dan KIT sederhana untuk mengajarkan keterampilan psikomotor peserta didik pada pokok bahasan alat optik (Implementation of simple PheT and KIT simulations to teach psychomotor skills of students on the subject of optical instruments).*Jurnal Pendidikan IPA, 2*(1), 18-22. https://journal.unnes.ac.id/nju/index.php/jpii/article/view/2505

Prisecaru, P. (2016). Challenges of the fourth industrial revolution. Knowledge horizons. *Economics, 8*(1), 5762.https://econpapers.repec.org/article/khejournl/v_ 3a8_3ay_3a2016_ 3ai_3a1_3ap_3a57-62.htm

Raja, V. (2016). Scientific attitude among Secondary School Students. https://www.researchgate.net/publication/332291791

Ramdani, A., Artayasa, I.P., Yustiqvar, M., and Nisrina, M. (2021). Enhancing prospective teachers' creative thinking skills: A study of the transition from structured to open inquiry Groupes. *Cakrawala Pendidikan, 40*(3), 637-649. https://doi.org/10.21831/cp.v40i3.41758

Rihatno, T., Amanda, F., Marini, A., Sagita, J., Safitri, A, & Maksum, A (2023). Development of interactive websites to increase learning interest in physical education learning. *Cypriot Journal of Educational Sciences 18*(1). https://doi.org/10.18844/cjes.v18i1.8262

Rusli, M. A., Tawil, M., Ramlawati, R., and Nur, M. K. B. Description of skills in reading measurement results by group VII students as aresult of distance learning during the covid-19 pandemic st SMPN 18 Makassar. *In International conference on science and advanced technology* (ICSAT), 121-127. https://ojs.unm.ac.id/icsat/article/view/17582

Saputra, R., Susilawati, S., and Verawati, N.N.S.P. (2020).Pengaruh penggunaan media simulasi PhET (physyc education technology) terhadap hasil belajar fisika (The effect of using PhET (physyc Education Technology) simulation media on physics learning outcomes.*Jurnal PIJAR MIPA, 15*(2), 110-115. https://doi.org/10.29303/jpm.v15i2,1459

Sinulingga, P., Hartanto, T.J. and Santoso, B. (2016). Implementasi pembelajaran fisika berbantuan media simulasi PhET untuk meningkatkan hasil belajar siswa pada materi listrik dinamis. (Implementation of PhET simulation media assisted physics learning to improve student learning outcomes on dynamic electricity material).*Jurnal Penelitian dan Pengembangan Pendidikan Fisika, 2*(1), 57-64. https://doi.org/10.21009/1.02109

Sulemen,T.S,. and Kumar,S. (2019). Study of relationship between scientific attitude and achievement in science 11th grade student. *Internatioal Journal for* *research in Engineering Application & Management (ijreaam)*, 5(1). 74-80. http://doi.org/10.18231/2454-91.50.2019

Surif, J., Ibrahim, N. H., and Hassan, R. A. (2014).Tahap amalan dan pengintegrasian ICT dalam proses pengajaran dan pembelajaran sains. (Stages of practice and integration of ICT in science teaching and learning process) *Sains Humanika*, *2*(4), 13-18. https://doi.org/10.11113/sh.v2n4.463.

Susantini, E., Faizah, U., Prastiwi, M.S., and Suryanti. (2016). Developing educational video to improve the use of scientific approach in cooperative learning. *Journal of Baltic Science Education*, *15*(6), 725-737. https://doi.org/10.33225/jbse/16.15.725

Tatli, Z., and Ayas, A. (2012). Virtual Chemistry Laboratory: Effect of constructivist learning environment. Turkish *Online Journal of Distance Education*, *13*(1), 183-199. https://dergipark.org.tr/en/pub/tojde/issue/16899/176130

Tawil, M., and Liliasari. (2014). *Keterampilan-keterampilan sains dan implementasinya dalam pembelajaran IPA*.(*science skills and their implementation in science learning*). UNM Press. https://badanpenerbit.unm.ac.id/

Tawil, M., Said, M, A., and Suryansari, K. (2022). Exploration the skills of teacher: implementation technological pedagogical content knowledge. *Cypriot Journal of Educational Sciences*, *17*(12), 4713–4733. https://doi.org/10.18844/cjes.v17i12.8593

Tomljenović, Z. (2020). The cognitive aspect of interactive learning and teaching in visual arts *education*. *Revija za elementarno izobraževanje. Journal of elementary education*. *13*(2), 131–152. https://doi.org/10.18690/rei.13.2.131-152.2020

Topalsan, A. K. (2020). Development of scientific inquiry skills of science teaching through argument-focused virtual laboratory applications. *Journal of Baltic Science Education*, *19*(4), 628-646. https://www.ceeol.com/search/article-detail?id=946163

Vasimalai Raja. (2019). Scientific attitude among secondary school students. *Bi-annual Journal in Education*,*III*(I), 1-9. https://doi.org/10.22183/23501081

Wong, W. K., Chen, K. P., and Chang, H. M. (2020). A comparison of a virtual Lab and a microcomputer-based Lab for scientific modelling by college students. *Journal of Baltic Science Education*, *19*(1), 157-173. https://www.ceeol.com/search/article-detail?id=947241

Yafie, E. D. (2019). *Pengembangan kognitif*.**(***Cognitive development*), 1-31 Malang: Universitas Negeri Malang.https://pustaka.ut.ac.id/lib/wp-content/uploads/pdfmk/PAUD410102-M1.pdf.

Zemljak, D., and Virtič, M, P. (2022). Are pedagogical students more creative than students of non-pedagogical programs? *Revija Za Elementarno IzobraževanjeJournal of Elementary Education*, 15(2),199–210.https://doi.org/10.18690/rei.15.2.199-210.2022