25 (2), 2024, 932-945

Jurnal Pendidikan MIPA

e-ISSN: 2685-5488 | p-ISSN: 1411-2531

http://jurnal.fkip.unila.ac.id/index.php/jpmipa/

Advance Physics Virtual Laboratory (ADPHYLAB): Its Implication in Improving Students' Science Process Skills in Atomic Spectroscopy Practicum

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Abstract: Understanding the concept of physics students can not be achieved through lectures alone, but required practicum. However, limited equipment makes practicum difficult to do as an example of atomic spectroscopy. However, the use of information technology-based media in the form of virtual laboratories can be used as an alternative choice without losing its essence to facilitate Science Process Skills (SPS). This study aims to compare the improvement of students' SPS in atomic spectroscopy practicum using Advance Physics Virtual Laboratory (ADPHYLAB) and LABSTER. This research is a modified type of comparative research. The research time was conducted for 3 meetings, located in the Physics Laboratory of FKIP UNTIRTA. The research subjects were 8 physics laboratory assistants. The results showed that the SPS N-Gain score in the group using ADPHYLAB obtained consecutive values for classification, measurement, data interpretation and inferring indicators of 0.73; 0.89; 0.71 and 0.94, falling into the high category. While the group using LABSTER obtained scores on classification and measurement indicators of 0.40 and 0.53, falling into the medium category. While in the data interpretation and inferring indicators of 0.79 and 0.80 fall into the high category. Based on the results of the study, it can be concluded that ADPHYLAB-based learning media can improve student SPS compared to LABSTER-based learning media.

Keywords: ADPHYLAB, virtual laboratory, LABSTER, science process skills, atomic spectroscopy.

▪ INTRODUCTION

Physics concepts cannot be understood by conventional learning alone, but need to be accompanied by direct experience in the form of practicum, so that concepts can be understood thoroughly (Aydin et al., 2015). In accordance with the results of research conducted by Sui et al., (2024), because it does not involve practicum in learning, physics concepts, especially those related to microscopic scales, are still difficult to understand. Practicum related to microscopic scale is indeed difficult to do due to limited tools (expensive) and dangerous materials (radioactive). In line with the information provided by the Physics Laboratory Coordinator of UNTIRTA (Sultan Ageng Tirtayasa University), microscopic scale physics practicum such as atomic spectroscopy cannot be carried out due to the absence of tools. In fact, atomic spectroscopy material is included in the core physics course and is one of the important materials, because it helps students understand the concept of atoms. The achievement of the lecture is that students are expected to be able to analyze the relationship between various physical quantities in the theory of special relativity, quantum phenomena and show how the concepts of core physics and radioactivity can be applied in technology and everyday life. Based on these

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DOI: http://dx.doi.org/10.23960/jpmipa/v25i2.pp932-945
Received: 16 August 2024
Accepted: 25 October 2024
Published: 10 November 2024

achievements, to meet student competence, especially in analyzing physical relationships in quantum phenomena, atomic spectroscopy practicum is needed.

To overcome the problem of limited equipment, practicum can be carried out through virtual laboratories, namely online media based on information technology which is the best solution by providing alternative types of practicum to students (Huang et al., 2022; Komaragiri et al., 2021). Referring to the achievements of previous lectures, and based on Edgar Dale's cone of experience theory (Gloviczki & Lawrence, 2018), the ability to analyze can be facilitated with media in the form of simulation/virtual laboratories without eliminating the essence of real practicum. The use of information technology-based media such as virtual laboratories also supports the SDGs (Sustainable Development Goals), especially in the social development pillar of the 4th goal, namely quality education. In the 4th goal there are corresponding indicators, namely 4.4.1. relating to the proportion of adolescents and adults with information and communication technology (ICT) skills (Edwards Jr et al., 2024; Freese et al., 2024).

There are several studies that focus on developing virtual laboratories in the field of physics, including virtual laboratories in electrical materials (Pribadi et al., 2024), virtual laboratories in thermodynamics courses (Suthar & Joshipura, 2023), and virtual laboratories in momentum and impulse materials (Rigoulet et al., 2024). Meanwhile, there is only one virtual laboratory on atomic spectroscopy that has developed, and the media is named LABSTER (Link: https://www.labster.com/simulations/ spectrophotometers-building-and-exploring-the-instrument). However, there are still shortcomings in the media, especially the features have not been able to facilitate Science Process Skills (SPS). Why is SPS important? The answer is that SPS is needed by students to improve their ability to find and express facts and build physics concepts through scientific processes (Arslan et al., 2023; Coleman et al., 2023). Therefore, concept understanding will be achieved when students are able to master the SPS (Varas et al., 2023). In addition, SPS is a very important skill in the 21st century (Roshid & Haider, 2024).

Science Process Skills (SPS) is divided into 2 categories, namely basic and integrated. Basic SPS includes several indicators including observation, classification, measurement, communication, prediction and drawing conclusions (Diaz-Borda et al., 2024). Meanwhile, integrated SPS includes several indicators, namely formulate hypotheses, interpret data, formulate models, experiment, define operationally, and identify and control variables (Elfeky et al., 2020). Based on research conducted by Ates & Aktamis, (2024), it is explained that practicum can improve students' SPS, because during its implementation, students need the ability to apply scientific methods which are none other than SPS itself. Therefore, media is needed that is in accordance with the demands of SPS. As for other research that has been conducted by Harisudin et al., (2023), namely the development of a virtual laboratory in the form of Advance Physics Virtual Laboratory (ADPHYLAB). This media is a virtual laboratory that can be used in atomic spectroscopy practicum, has several advantages, namely being able to measure the wavelength of the emission spectrum of various atoms (H, He, and Hg), equipped with a presentation of basic theory, and can be accessed openly (Link: https://mersics.com/media/adphylab/). Not only that, ADPHYLAB also has features to facilitate student SPS including Theory, Procedure, Simulator and Conclusion (TePoSiCo), although the research has only reached the development stage. Based on

these advantages, ADPHYLAB can be an alternative in atomic spectroscopy practicum. Therefore, based on the previous description, this study aims to compare the improvement of students' SPS in atomic spectroscopy practicum using ADPHYLAB and LABSTER.

▪ METHOD

The population used in this research were 21 physics laboratory assistants. The sampling method used in this research is a random sampling sample to select research subjects. In the sampling method, wheel of names was used as a tool, 8 people were selected as research subjects. The reason for choosing physics laboratory assistants as subjects, because this study wants to reveal the mastery of SPS by using 2 different learning media, namely ADPHYLAB and LABSTER. Before assisting students/practitioners in atomic spectroscopy practicum, laboratory assistants must have good SPS and master the media used considering that laboratory assistants have never carried out the practicum. This research is a modified comparative research. The research was conducted for 3 meetings in May - June, at the Physics Laboratory of the Faculty of Teacher Training and Education, Sultan Ageng Tirtayasa University. The variables in this study include learning media, namely ADPHYLAB and LABSTER as independent variables, SPS improvement as the dependent variable, and the length of learning time as the control variable.

The research implementation was designed as shown in Figure 1. This design was chosen to see whether the provision of learning media had an effect on improving students' SPS.

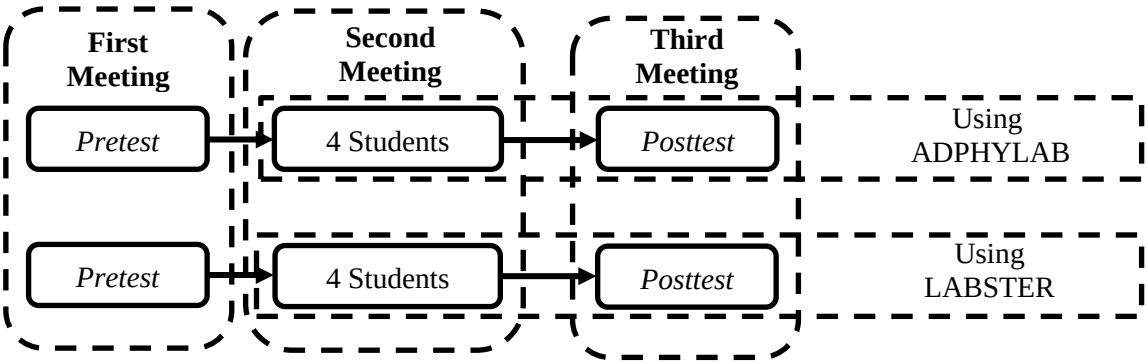


Figure 1. Research design

Based on Figure 1, at the first meeting the pretest was given to the subject which aims to find out the SPS of the laboratory assistant before carrying out the atomic spectroscopy practicum. The pretest was conducted for 1 hour. One week later, the 2nd meeting was held, where 8 subjects were randomly divided into 2 groups. Group A consisted of 4 subjects who used ADPHYLAB learning media, and group B consisted of 4 subjects who used LABSTER learning media. The time of using ADPHYLAB and LABSTER was limited to a maximum of 2 hours. The 3rd meeting was held 1 week later and 8 subjects were given a posttest after using the media. The posttest was conducted for 1 hour.

Test and non-test instruments were used in this study. The test instrument used is a pretest-posttest in the form of an essay, consisting of 8 items based on the predetermined SPS indicators, namely classification, measurement, data interpretation, and inferring.

This test instrument was adopted from research (Harisudin et al., 2023) which stated that it was in the good category. In addition, the non-test instrument used is an interview guide. The research question (RQ) asked in this study, namely: How is the difference in the improvement of students' SPS in atomic spectroscopy practicum using ADPHYLAB and LABSTER? There are several interview questions as a deepening that was asked including:

1. What is your experience in using ADPHYLAB/LABSTER?
2. How difficult is it for you to use ADPHYLAB/LABSTER?
3. How is your SPS after doing the atomic spectroscopy practicum using ADPHYLAB/LABSTER?

All instruments can be accessed through the link: https://bit.ly/Supplementalmaterial. The improvement of SPS was seen from the N-Gain score, while the deepening of the improvement results was seen from the interview results. Data analysis using N-Gain with interpretation according to Table 1.

Table 1. N-Gain criteria (Guntara, 2021)

Range Score Gain	Interpretation
$0.7<(g)<1$	High
$0.3\leq(g)\leq0.7$	Medium
$0<(g)<0.3$	Low

▪ RESULT AND DISSCUSSION

The results of this study are data on student improvement in terms of each indicator of SPS (Science Process Skills) in atomic spectroscopy practicum using two learning media, namely ADPHYLAB and LABSTER, as well as the results of deepening through interviews. The results and discussion of this study are presented in five sections. Section-1, related to the classification indicator, explains how students can classify the characteristics of atoms. Section-2, related to the measurement indicator, discusses how students can measure the angle of the atomic spectral sequence. Section-3, deals with the data interpretation indicator to see if students are able to interpret the wavelength of the wavelength correctly. Section-4, discusses the inferring indicator which explains how the subject can infer the energy levels of some atoms (H, He, Hg). Section-5, discusses several aspects related to the subject's experience after using a virtual laboratory, namely ADPHYLAB or LABSTER.

RQ: How does the Subject's SPS Improvement Differ Using ADPHYLAB with LABSTER?

The improvement of SPS based on each indicator can be seen in Figure 2. The average difference score of pretest and posttest SPS of subjects using ADPHYLAB is higher than that of subjects using LABSTER. It can be seen in Figure 2, which shows the average difference score of pretest and posttest SPS of subjects using ADPHYLAB and LABSTER.

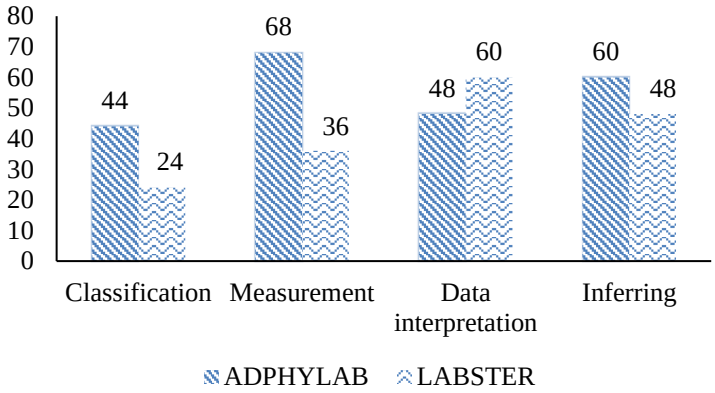


Figure 2. Distribution of student SPS improvement based on each indicator

Table 2. N-Gain analysis calculation results

Learning Media	N-Gain			
	Classification	**Measurement**	**Data Interpretation**	**Inferring**
ADPHYLAB	0.73	0.89	0.71	0.94
LABSTER	0.40	0.53	0.79	0.80

The results of the N-Gain analysis showed that the average score of SPS subjects who used ADPHYLAB in the classification indicator obtained a value of 0.73 which was included in the high category, the measurement indicator obtained a value of 0.89 including in the high category, the data interpretation indicator obtained a value of 0.71 including in the high category, and the inferring indicator obtained a value of 0.94 including in the high category. Meanwhile, subjects who used LABSTER on classification indicators obtained a value of 0.40 which was included in the medium category, measurement indicators obtained a value of 0.53 including in the medium category, data interpretation indicators obtained a value of 0.79 including in the high category, and inferring indicators obtained a value of 0.80 including in the high category.

Based on Table 2, it can be seen that three SPS indicators are superior to those mastered by subjects using ADPHYLAB, namely in the classification, measurement and inferring indicators. While a more detailed discussion, explained as follows:

Student SPS on Classification Indicators

Based on Figure 2, it can be seen that the increase in SPS on the classification indicator, ADPHYLAB is superior to LABSTER. In the classification indicator, students are required to be able to classify events, objects, and opinions based on certain characteristics possessed by atoms.

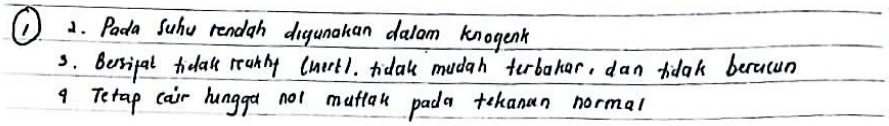


Figure 3. Example of classification indicator answer

Figure 3, shows the answer of one of the subjects who did not master the classification indicator and the subject used LABSTER. Based on Figure 3, the subject did not explain the reason for the characteristics of the atom, this is an incorrect answer. The answer given shows that the subject has low ability in the classification indicator. In this item, when viewed from the material, the subject needs to master material related to atomic characteristics. The subject's answer should be able to classify correctly, then explain the reasons for the selected characteristic points clearly and correctly.

However, if you look at the answer in Figure 3, the subject has difficulty, namely not understanding the intention or direction of the problem. The subject was fooled by unnecessary information and made it as an answer. Based on Krstić's research, (2018) the subject is less skilled in identifying differences and similarities between various objects observed. This condition can be overcome by getting used to giving questions so that the subject can filter the information needed (Roisah et al., 2023). The ability to select or filter this information greatly affects the mastery of classification indicators.

Based on the relationship between learning media and indicators, the subject's SPS can increase on the classification indicator because ADPHYLAB has Theory features that contain information needed in classifying events, objects, and opinions based on certain characteristics that atoms have. In order for the subject to classify, atomic material is provided as a stimulus in the basic theory sub-menu. The other sub-menus display the characteristics of atoms to determine the atoms used and display visuals of atomic spectroscopy.

Student SPS on Measurement Indicators

Based on Figure 2, it can be seen that the increase in SPS on the measurement indicator, ADPHYLAB is superior to LABSTER. In the measurement indicator, students are required to be able to express the character of objects or materials numerically on the atomic emission spectrum.

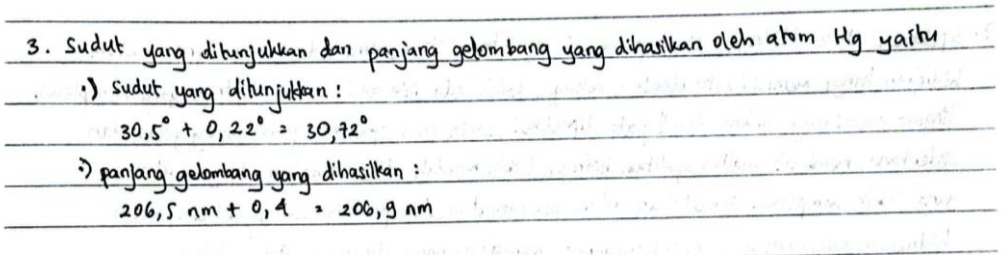


Figure 4. Example of measurement indicator answer

Figure 4, shows the answer of one of the subjects who did not master the measurement indicator and the subject used LABSTER. Based on Figure 4, the subject was unable to measure the wavelength of the atom, which is an incorrect answer. The answer given shows that the subject has a low ability in the measurement indicator. In this item, when viewed from the material the subject needs to master material related to how to use the Hilger spectrometer. The subject's answer should can measure correctly, then calculate the wavelength of the atomic emission spectrum correctly. However, if you look at the answer in Figure 4, the subject has difficulty, namely not knowing how to use atomic spectroscopy measuring instruments. In addition, the subject read the atomic

spectroscopy measuring instrument like reading a screw micrometer. The subject was fooled by the information presented because he did not have experience using the Hilger spectrometer measuring instrument. Based on Wu et al., (2016) the subject is less skilled in measurement indicators because the subject is not familiar with measuring SPS questions that are done in writing, not only that, inaccuracy in observing the scale in the problem is also a cause of the low ability to measure the observed object. This condition can be overcome by implementing a counting system that makes it easy to learn each unit used in measuring instruments (Philip Chen & Zhang, 2014). The ability to master measurement indicators is very necessary in making effective quantity observations.

Based on the relationship between learning media and indicators, the subject's SPS can increase on the measurement indicator because ADPHYLAB has a Simulator feature that contains the information needed to numerically express the character of objects or materials in the atomic emission spectrum. So that the subject can measure the angle of the spectral sequence produced by the Hilger spectro meter.

Student SPS on Data Interpretation Indicators

Based on Figure 2, it can be seen that the increase in SPS in the data interpretation indicator, LABSTER is superior to ADPHYLAB. In the data interpretation indicator, students are required to be able to interpret data that is grouped or tabulated from the results of atomic spectroscopy practicum.

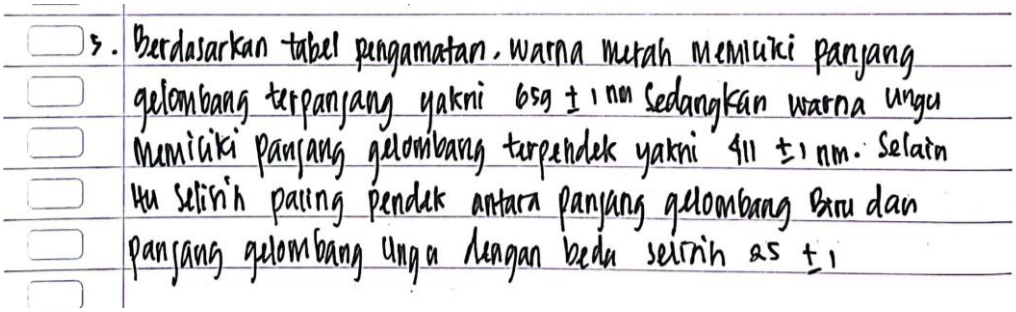


Figure 5. Example of data interpretation indicator answers

Figure 5, shows the answer of one of the subjects who did not master the data interpretation indicator and the subject used ADHPYLAB. Based on Figure 5 was not able to interpret the data from the atomic spectroscopy practicum results, this is an incorrect answer. The answer given shows that the subject has a low ability in the data interpretation indicator. In this item, when viewed from the material, the subject needs to master material related to factors and the results of measuring the wavelength of the atomic emission spectrum. The subject's answer should be able to interpret the results of the practicum correctly, then compare with the existing theory. However, if you look at the answer in Figure 5. the subject has difficulty, namely not knowing how to process the information that has been presented. In addition, the subject only rewrote the results of the atomic spectroscopy practicum. The subject was fooled by the information presented because he was not used to analyzing existing data. Based on Papamitsiou & Economides's research, (2014) subjects are less skilled in data interpretation indicators due to a lack of intrinsic ability to recognize patterns and associations in data. This

condition can be overcome by analyzing and processing data based on directions from educators after conducting experiments (Phonna & Arusman, 2018).

Based on the relationship between learning media and indicators, the subject's SPS can increase in the data interpretation indicator because LABSTER has a 3-dimensional display that is needed in interpreting data grouped or tabulated from the results of atomic spectroscopy practicum. So that, the subject can interpret the data obtained from the refraction of the resulting electromagnetic wavelength.

Student SPS on Inferring Indicator

Based on Figure 2, it can be seen that the increase in SPS on the inferring indicator, ADPHYLAB is superior to LABSTER. In the inferring indicator, students are required to be able to make conclusions related to events or situations on the concept of atomic spectroscopy.

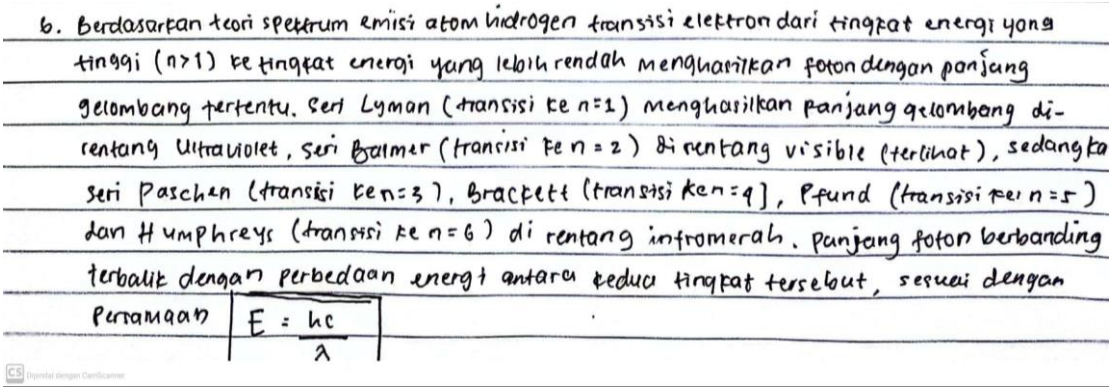
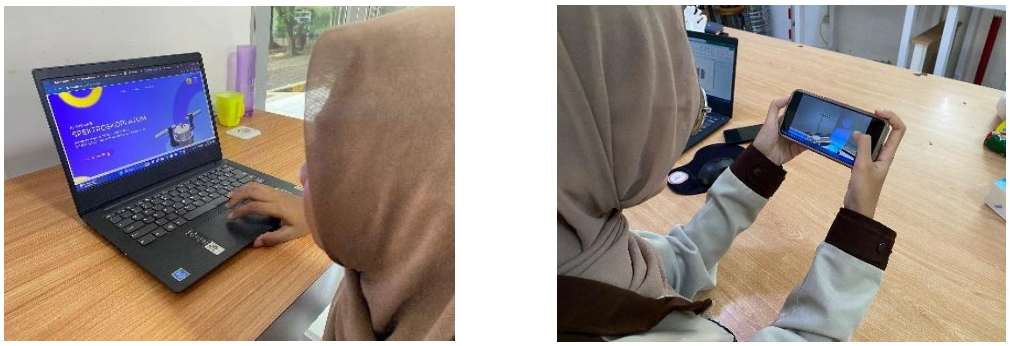

6. Berdasarkan teori spektrum emisi atom hidrogen transisi elektron dari tingkat energi yang tinggi (n>1) ke tingkat energi yang lebih rendah menghasilkan foton dengan panjang gelombang tertentu. Seri Lyman (transisi ke n=1) menghasilkan panjang gelombang di-rentang Ultraviolet, seri Balmer (transisi ke n=2) di rentang visible (terlihat), sedangka seri Paschen (transisi ke n=3), Brackett (transisi ke n=4), Pfund (transisi ke n=5) dan Humphreys (transisi ke n=6) di rentang infromerah. Panjang foton berbanding terbalik dengan perbedaan energi antara kedua tingkat tersebut, sesuai dengan persamaan $E = \frac{hc}{\lambda}$

Figure 6. Sample answer for inferring indicator

Figure 6, shows the answer of one of the subjects who did not master the inferring indicator and the subject used LABSTER. Based on Figure 6, the subject experienced difficulties, namely not being able to infer data related to atomic spectroscopy based on existing theories. The answer given shows that the subject has a low ability in the inferring indicator. In this item, when viewed from the material, the subject needs to master material related to energy levels in several atoms (H, He, Hg) formed from several spectral sequences. The subject's answer should be able to draw conclusions based on the concept of atomic spectroscopy that has been learned. Based on research by Rochmadona & Nurita, (2021) subjects need to construct knowledge through the assimilation process from new experiences into existing knowledge so that students can easily conclude an event correctly. This condition can also be overcome, during the learning process the subject must reconstruct the knowledge obtained from the educator with direct subject involvement through an experiment (Arifin & Handayani, 2019).

Based on the relationship between learning media and indicators, the subject's SPS can increase in the inferring indicator because ADPHYLAB has a Conclusion feature that contains assessment of learning and the results of assessment as learning needed in making conclusions related to events or situations on the concept of atomic spectroscopy.

Comparison of Experience Using ADPHYLAB and LABSTER



(a) (b)

Figure 7. (a) Using of ADPHYLAB, (b) Using of LABSTER

Based on the results of interviews with the research subjects, several findings were obtained that. Subjects who use ADPHYLAB have no problems when doing atomic spectroscopy practicum and understand how to work on how to measure atomic emission spectra using the Hilger spectrometer so that they get new experiences and can be accessed openly, but the display is 2-dimensional so that the subject has less exploration related to atomic spectroscopy practicum due to limited visualization. Meanwhile, subjects who use LABSTER have a new experience by doing practicum in 3 dimensions so that it makes it easier to explore related to atomic spectroscopy practicum, but the features on LABSTER are not equipped with introductory theory regarding the atomic emission spectrum so that the subject experiences confusion when doing practicum, not only that when using LABSTER the subject does not get the experience of using the Hilger spectrometer but only sees the atomic emission spectrum through a spectrometer with prism refraction, and LABSTER can only be accessed after making a payment.

From the analysis above, the use of ADHPYLAB-based learning media is superior to LABSTER-based learning media in improving SPS. This is because ADPHYLAB has several features, namely: Theory, Procedure, Simulator, and Conclusion (TePoSiCo) in improving students' SPS in atomic spectroscopy practicum. This is due to the relationship between ADPHYLAB learning media and SPS indicators shown in Figure 8.

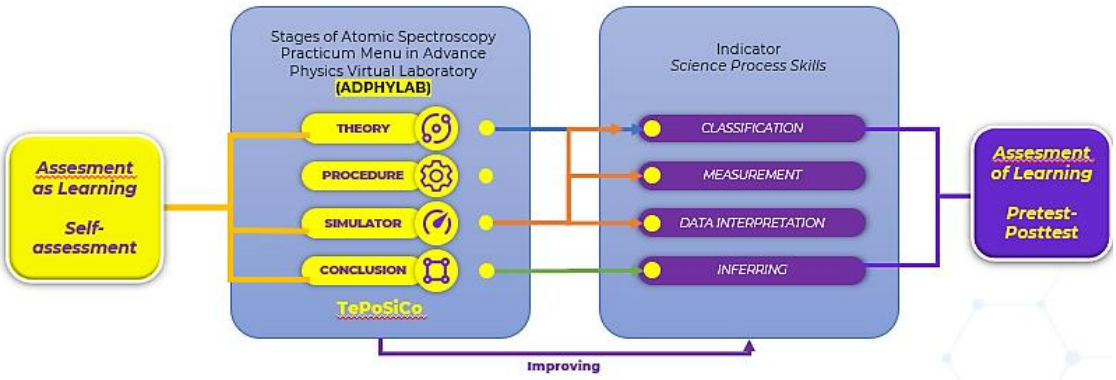


Figure 8. Relationship between ADPHYLAB learning media and SPS indicators

The Te (Theory) feature is used to facilitate classification indicators in line with previous research conducted by (Park & Kremer, 2017). So that students can classify, atomic spectroscopy material is provided as a stimulus in the theory base sub-menu. The other sub-menu displays the use of atoms to find out the atoms used and the "maintenance" sub-menu displays visuals of atomic spectroscopy, tutorials on using ADPHYLAB and practicum worksheets. The Po (Procedure) feature displays the objectives of the practicum, tools and materials and practicum procedures. In addition, the Si (Simulator) feature can facilitate measurement indicators of data interpretation, and classification based on research that has been done (Akhavian & Behzadan, 2015). For students to be able to measure and interpret data, an "experiment" menu is provided which can measure the angle of the spectral sequence produced by the Hilger spectrometer and students can interpret the data obtained into electromagnetic wavelengths. So that students can classify the spectral series of Hydrogen, Helium, and Mercury atoms. The Co (Conclusion) feature facilitates conclusion indicators, in line with research conducted by (Fau & Moreau, 2018). On the "collect here" menu, students can collect practicum worksheets, the menu also has an assessment of learning in the spectroscopy quiz section and assessment as learning results by displaying the "adphylabmania" profile as a self-assessment to measure SPS improvement.

From the results of the research that has been done, it can be stated that ADPHYLAB and LABSTER have their own advantages and disadvantages. If it aims to improve students' SPS, the author prefers to use ADPHYLAB because it has features that are suitable in improving SPS, while if it aims to explore the process of refraction of atomic emission spectra, the author suggests using LABSTER. Virtual laboratories, especially ADPHYLAB, can be the best solution in preparing or being a means of practicing atomic spectroscopy.

▪ CONCLUSION

The results showed that the N-Gain score of Science Process Skills (SPS) in the group using Advance Physics Virtual Laboratory (ADPHYLAB) obtained consecutive values for classification, measurement, data interpretation and inferring indicators of 0.73; 0.89; 0.71 and 0.94, into the high category. Whereas in the group that used LABSTER obtained scores on classification and measurement indicators of 0.40 and 0.53, falling into the medium category. While in the data interpretation and inferring indicators of 0.79 and 0.80 fall into the high category. Based on the results of the study, it can be concluded that ADPHYLAB-based learning media can improve student SPS compared to LABSTER-based learning media.

From this study, it can be seen that students' SPS can improve better by using ADPHYLAB because it has appropriate features compared to using LABSTER. As for the shortcomings of this study, namely the population used in its application is not yet broad because atomic spectroscopy practicum has never been done. Therefore, further research is needed to determine the effectiveness of using ADPHYLAB on a wider scale.

▪ REFERENCES

Akhavian, R., & Behzadan, A. H. (2015). Construction equipment activity recognition for simulation input modeling using mobile sensors and machine learning classifiers. Advanced Engineering Informatics, 29(4), 867–877.

Arifin, Z., & Handayani, B. L. (2019). Construction of students knowledge of disasters based on curriculum 13 in jember district. Jurnal ENTITAS SOSIOLOGI, 8(2), 78.

Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. Teaching and Teacher Education, 121, 103905.

Ates, C. B., & Aktamis, H. (2024). Investigating the effects of creative educational modules blended with Cognitive Research Trust (CoRT) techniques and Problem Based Learning (PBL) on students' scientific creativity skills and perceptions in science education. Thinking Skills and Creativity, 51, 101471.

Aydin, S., Demirdogen, B., Akin, F. N., Uzuntiryaki-Kondakci, E., & Tarkin, A. (2015). The nature and development of interaction among components of pedagogical content knowledge in practicum. Teaching and Teacher Education, 46, 37–50.

Coleman, A., Eser, J., Mayotte, E., Sarazin, F., Schröder, F. G., Soldin, D., Venters, T. M., Aloisio, R., Alvarez-Muñiz, J., & Batista, R. A. (2023). Ultra high energy cosmic rays The intersection of the Cosmic and Energy Frontiers. Astroparticle Physics, 149, 102819.

Desy Rochmadona, A., & Nurita, T. (2021). Penerapan model discovery learning pada pembelajaran daring untuk meningkatkan keterampilan proses sains siswa di smp negeri 1 sidoarjo. Pensa E-Jurnal : Pendidikan Sains, 9(3), 266–271. https://ejournal.unesa.ac.id/index.php/pensa

Diaz-Borda, G. A., Garcia-Zambrano, S., & Flores, E. P. (2024). Behavioral interventions for teaching perspective-taking skills: a scoping review. Journal of Contextual Behavioral Science, 100816.

Edwards Jr, D. B., Asadullah, M. N., & Webb, A. (2024). Critical perspectives at the mid-point of Sustainable Development Goal 4: Quality education for all—progress, persistent gaps, problematic paradigms, and the path to 2030. International Journal of Educational Development, 107, 103031.

Elfeky, A. I. M., Masadeh, T. S. Y., & Elbyaly, M. Y. H. (2020). Advance organizers in flipped classroom via e-learning management system and the promotion of integrated science process skills. Thinking Skills and Creativity, 35, 100622.

Fau, S., & Moreau, Y. (2018). Managing tomorrow's digital skills-what conclusions can we draw from international comparative indicators?

Freese, T., Elzinga, N., Heinemann, M., Lerch, M. M., & Feringa, B. L. (2024). The relevance of sustainable laboratory practices. Rsc Sustainability, 2(5), 1300–1336.

Gloviczki, P., & Lawrence, P. F. (2018). Visual abstracts bring key message of scientific research. Journal of Vascular Surgery, 67(5), 1319–1320.

Guntara, Y. (2021). Normalized gain: ukuran keefektifan treatment. Universitas Sultan Ageng Tirtayasa, 1–3.

Harisudin, A., Saefullah, A., & Guntara, Y. (2023). *Pengembangan advance physics virtual laboratory (ADPHYLAB) pada pada praktikum spektroskopi atom untuk memfasilitasi keterampilan proses sains.* Prosiding Seminar Pendidikan Fisika (SENDIKFI), 5(1).

Huang, Y., Richter, E., Kleickmann, T., & Richter, D. (2022). Class size affects preservice teachers' physiological and psychological stress reactions: An experiment in a virtual reality classroom. Computers & Education, 184, 104503.

Komaragiri, S., Gigliotti, A., & Bhasin, A. (2021). Calibration and extended validation of a virtual asphalt mixture compaction model using bullet physics engine. Construction and Building Materials, 311, 125257.

Krstić, K., Šoškić, A., Ković, V., & Holmqvist, K. (2018). All good readers are the same, but every low-skilled reader is different: an eye-tracking study using PISA data. European Journal of Psychology of Education, 33(3), 521–541.

Papamitsiou, Z., & Economides, A. A. (2014). Learning analytics and educational data mining in practice: A systemic literature review of empirical evidence. Educational Technology and Society, 17(4), 49–64.

Park, K., & Kremer, G. E. O. (2017). Text mining-based categorization and user perspective analysis of environmental sustainability indicators for manufacturing and service systems. Ecological Indicators, 72, 803–820.

Philip Chen, C. L., & Zhang, C. Y. (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. Information Sciences, 275, 314–347. https://doi.org/10.1016/j.ins.2014.01.015

Phonna, Z., & Arusman. (2018). Pengaruh model predict-observe-explain terhardap keterampilan proses sains peserta didik. Jurnal Mimbar Akademik, 3(2), 86–99.

Pribadi, A. P., Rahman, Y. M. R., & Silalahi, C. D. A. B. (2024). Analysis of the effectiveness and user experience of employing virtual reality to enhance the efficacy of occupational safety and health learning for electrical workers and graduate students. Heliyon, 10(15).

Rigoulet, T., Blanc, L., Daghia, F., & Wriggers, P. (2024). A numerical and experimental approach to blast protection with fluids, effect of impulse spreading. International Journal of Impact Engineering, 105094.

Roisah, R., Kusrina, T., & Porwanto, B. E. (2023). *Model pembelajaran kooperatif tipe think talk write (ttw) dapat meningkatkan kemampuan berfikir kritis dan prestasi belajar pada mata pelajaran ips.* Journal of Education Research, 4(3), 1481–1487. https://doi.org/10.37985/jer.v4i3.355

Roshid, M. M., & Haider, M. Z. (2024). Teaching 21st-century skills in rural secondary schools: From theory to practice. Heliyon, 10(9).

Sui, H., Liu, W., Zhang, Y., & Duan, H. (2024). Multi-scale spallation model for single-crystal ductile metals incorporating microscopic mechanism of void nucleation. Journal of the Mechanics and Physics of Solids, 183, 105520.

Suthar, K. J., & Joshipura, M. H. (2023). The integrative approach of learning chemical engineering thermodynamics by using simulation-based exercises. Education for Chemical Engineers, 45, 122–129.

Varas, D., Santana, M., Nussbaum, M., Claro, S., & Imbarack, P. (2023). Teachers' strategies and challenges in teaching 21st century skills: Little common understanding. Thinking Skills and Creativity, 48, 101289.

Wu, M., Tam, H. P., & Jen, T.-H. (2016). Educational measurement for applied researchers. Theory into Practice, 136.

Akhavian, R., & Behzadan, A. H. (2015). Construction equipment activity recognition for simulation input modeling using mobile sensors and machine learning classifiers. Advanced Engineering Informatics, 29(4), 867–877.

Arifin, Z., & Handayani, B. L. (2019). Construction of students knowledge of disasters based on curriculum 13 in jember district. Jurnal Entitas Sosiologi, 8(2), 78. https://doi.org/10.19184/jes.v8i2.16653

Arslan, H. O., Genc, M., & Durak, B. (2023). Exploring the effect of argument-driven inquiry on pre-service science teachers' achievement, science process, and argumentation skills and their views on the ADI model. Teaching and Teacher Education, 121, 103905.

Ates, C. B., & Aktamis, H. (2024). Investigating the effects of creative educational modules blended with Cognitive Research Trust (CoRT) techniques and Problem Based Learning (PBL) on students' scientific creativity skills and perceptions in science education. Thinking Skills and Creativity, 51, 101471.

Aydin, S., Demirdogen, B., Akin, F. N., Uzuntiryaki-Kondakci, E., & Tarkin, A. (2015). The nature and development of interaction among components of pedagogical content knowledge in practicum. Teaching and Teacher Education, 46, 37–50.

Coleman, A., Eser, J., Mayotte, E., Sarazin, F., Schröder, F. G., Soldin, D., Venters, T. M., Aloisio, R., Alvarez-Muñiz, J., & Batista, R. A. (2023). Ultra high energy cosmic rays The intersection of the Cosmic and Energy Frontiers. Astroparticle Physics, 149, 102819.

Desy Rochmadona, A., & Nurita, T. (2021). *Penerapan model discovery learning pada pembelajaran daring untuk meningkatkan keterampilan proses sains siswa di smp negeri 1 sidoarjo.* Pensa E-Jurnal : Pendidikan Sains, 9(3), 266–271. https://ejournal.unesa.ac.id/index.php/pensa

Diaz-Borda, G. A., Garcia-Zambrano, S., & Flores, E. P. (2024). Behavioral interventions for teaching perspective-taking skills: a scoping review. Journal of Contextual Behavioral Science, 100816.

Edwards Jr, D. B., Asadullah, M. N., & Webb, A. (2024). Critical perspectives at the mid-point of Sustainable Development Goal 4: Quality education for all—progress, persistent gaps, problematic paradigms, and the path to 2030. International Journal of Educational Development, 107, 103031.

Elfeky, A. I. M., Masadeh, T. S. Y., & Elbyaly, M. Y. H. (2020). Advance organizers in flipped classroom via e-learning management system and the promotion of integrated science process skills. Thinking Skills and Creativity, 35, 100622.

Fau, S., & Moreau, Y. (2018). Managing tomorrow's digital skills-what conclusions can we draw from international comparative indicators?

Freese, T., Elzinga, N., Heinemann, M., Lerch, M. M., & Feringa, B. L. (2024). The relevance of sustainable laboratory practices. Rsc Sustainability, 2(5), 1300–1336.

Gloviczki, P., & Lawrence, P. F. (2018). Visual abstracts bring key message of scientific research. Journal of Vascular Surgery, 67(5), 1319–1320.

Guntara, Y. (2021). Normalized gain: ukuran keefektifan treatment. Universitas Sultan Ageng Tirtayasa, 1–3.

Harisudin, A., Saefullah, A., & Guntara, Y. (2023). Pengembangan advance physics virtual laboratory (ADPHYLAB) pada pada praktikum spektroskopi atom untuk memfasilitasi keterampilan proses sains. Prosiding Seminar Pendidikan Fisika (SENDIKFI), 5(1).

Huang, Y., Richter, E., Kleickmann, T., & Richter, D. (2022). Class size affects preservice teachers' physiological and psychological stress reactions: An experiment in a virtual reality classroom. Computers & Education, 184, 104503.

Komaragiri, S., Gigliotti, A., & Bhasin, A. (2021). Calibration and extended validation of a virtual asphalt mixture compaction model using bullet physics engine. Construction and Building Materials, 311, 125257.

Krstić, K., Šoškić, A., Ković, V., & Holmqvist, K. (2018). All good readers are the same, but every low-skilled reader is different: an eye-tracking study using PISA data. European Journal of Psychology of Education, 33(3), 521–541. https://doi.org/10.1007/s10212-018-0382-0

Papamitsiou, Z., & Economides, A. A. (2014). Learning analytics and educational data mining in practice: A systemic literature review of empirical evidence. Educational Technology and Society, 17(4), 49–64.

Park, K., & Kremer, G. E. O. (2017). Text mining-based categorization and user perspective analysis of environmental sustainability indicators for manufacturing and service systems. Ecological Indicators, 72, 803–820.

Philip Chen, C. L., & Zhang, C. Y. (2014). Data-intensive applications, challenges, techniques and technologies: A survey on Big Data. Information Sciences, 275, 314–347. https://doi.org/10.1016/j.ins.2014.01.015

Phonna, Z., & Arusman. (2018). *Pengaruh model predict-observe-explain terhardap keterampilan proses sains peserta didik.* Jurnal Mimbar Akademik, 3(2), 86–99.

Pribadi, A. P., Rahman, Y. M. R., & Silalahi, C. D. A. B. (2024). Analysis of the effectiveness and user experience of employing virtual reality to enhance the efficacy of occupational safety and health learning for electrical workers and graduate students. Heliyon, 10(15).

Rigoulet, T., Blanc, L., Daghia, F., & Wriggers, P. (2024). A numerical and experimental approach to blast protection with fluids, effect of impulse spreading. International Journal of Impact Engineering, 105094.

Roisah, R., Kusrina, T., & Porwanto, B. E. (2023). *Model pembelajaran kooperatif tipe think talk write (ttw) dapat meningkatkan kemampuan berfikir kritis dan prestasi belajar pada mata pelajaran ips.* Journal of Education Research, 4(3), 1481–1487. https://doi.org/10.37985/jer.v4i3.355

Roshid, M. M., & Haider, M. Z. (2024). Teaching 21st-century skills in rural secondary schools: From theory to practice. Heliyon, 10(9).

Sui, H., Liu, W., Zhang, Y., & Duan, H. (2024). Multi-scale spallation model for single-crystal ductile metals incorporating microscopic mechanism of void nucleation. Journal of the Mechanics and Physics of Solids, 183, 105520.

Suthar, K. J., & Joshipura, M. H. (2023). The integrative approach of learning chemical engineering thermodynamics by using simulation-based exercises. Education for Chemical Engineers, 45, 122–129.

Varas, D., Santana, M., Nussbaum, M., Claro, S., & Imbarack, P. (2023). Teachers' strategies and challenges in teaching 21st century skills: Little common understanding. Thinking Skills and Creativity, 48, 101289.

Wu, M., Tam, H. P., & Jen, T.-H. (2016). Educational measurement for applied researchers. Theory into Practice, 136.