# Application of The Physics Aviary Virtual Laboratory to Support Student Motivation and Self-Regulated Learning

Nurlina[1], Nur Aisyah Humairah[2], Ummu Kalsum[3], Fauziah. A[4], Maisarah[5], Widia[6], Wita Fardilla[7]

Universitas Sulawesi Barat, Indonesia,[1,2,3,4,5,6,7]
{nurlina@unsulbar.ac.id[1], nuraisyah.humairah@unsulbar.ac.id[2], ummukalsum580@gmail.com[3], fauziah.a@unsulbar.ac.id[4], smai32347@gmail.com[5], widiataufik655@gmail.com[6], pardillahw@gmail.com[7]}

*Submission*: 2025-08-13 *Received*: 2025-09-22 *Published*: 2025-09-30

*Keywords:* *Virtual Laboratory, The Physics Aviary, Motivation, Self-Regulated Learning.*

**Abstract.** *Limited access to adequate physics laboratory facilities remains a major challenge in Indonesian schools, including SMAN 1 Mamasa, where conventional physics learning often lacks hands-on experiments. To address this issue, this study was conducted as part of a Community Service (PkM) activity, providing training and mentoring on the use of The Physics Aviary (TPA) virtual laboratory for eleventh-grade students. The activity employed Community-Based Research (CBR) and Service Learning approaches, enabling students to actively participate in meaningful learning experiences while contributing to the community. A total of 34 students (20 females, 14 males) participated in the program, which was conducted from July to August 2025. Data on learning motivation and self-regulated learning (SRL) were collected using validated questionnaires and analyzed descriptively. The results indicate that the virtual laboratory effectively fostered students' intrinsic motivation, with the highest scores observed in intrinsic goal orientation (mean = 4.12, SD = 0.95) and task value (mean = 4.06, SD = 0.89). Additionally, SRL skills were reflected in high scores for time and study environment management (mean = 4.06, SD = 0.81) and peer learning (mean = 3.91, SD = 0.99). Student satisfaction with the training was also high, demonstrating successful implementation. This PkM activity not only introduced TPA in the local school context but also provided initial empirical evidence that virtual labs can serve as effective alternatives for fostering motivation and self-regulation in secondary physics education. However, the findings highlight the need to strengthen metacognitive and collaborative learning aspects.*

Katakunci:
*Laboratorium Virtual, The Physics Aviary, Motivasi, Kemandirian Belajar.*

**Abstrak.** Akses terhadap fasilitas laboratorium fisika yang memadai masih menjadi tantangan utama di sekolah-sekolah Indonesia, termasuk SMAN 1 Mamasa, di mana pembelajaran fisika konvensional seringkali minim kegiatan praktikum langsung. Untuk mengatasi masalah ini, kegiatan ini dilakukan sebagai bagian dari Pengabdian kepada Masyarakat (PkM), yang menyediakan pelatihan dan pendampingan penggunaan laboratorium virtual The Physics Aviary (TPA) bagi siswa kelas sebelas. Kegiatan ini menerapkan pendekatan *Community Based Research* (CBR) dan *Service Learning*, yang memungkinkan mahasiswa secara aktif berpartisipasi dalam pengalaman belajar yang bermakna sekaligus memberikan kontribusi kepada masyarakat. Sebanyak 34 siswa (20 perempuan, 14 laki-laki) mengikuti program ini, yang dilaksanakan pada Juli–Agustus 2025. Data mengenai motivasi belajar dan *self-regulated learning* (SRL) dikumpulkan melalui kuesioner yang telah divalidasi dan dianalisis secara deskriptif. Hasil menunjukkan bahwa laboratorium virtual secara efektif meningkatkan motivasi intrinsik siswa, dengan skor tertinggi pada orientasi tujuan intrinsik (rata-rata = 4,12; SD = 0,95) dan nilai tugas (rata-rata = 4,06; SD = 0,89). Selain itu, keterampilan SRL tercermin dari skor tinggi pada pengelolaan waktu dan lingkungan belajar (rata-rata = 4,06; SD = 0,81) serta pembelajaran teman sebaya (rata-rata = 3,91; SD = 0,99). Kepuasan siswa terhadap pelatihan juga tinggi, menunjukkan keberhasilan implementasi. Kegiatan PkM ini tidak hanya memperkenalkan TPA di konteks sekolah lokal, tetapi juga memberikan bukti awal secara empiris bahwa laboratorium virtual dapat menjadi alternatif efektif untuk meningkatkan motivasi dan kemandirian belajar dalam pembelajaran fisika di tingkat menengah. Namun, temuan ini menunjukkan perlunya penguatan aspek pembelajaran metakognitif dan kolaboratif.

## 1 Introduction

Physics learning requires theoretical mastery and experimental practice in the laboratory (Humairah et al., 2023; Miškář, 2019; Nurlina et al., 2024). However, in many regions, limited laboratory facilities pose a major obstacle to conducting experimental learning (Nurlina et al., 2025; Rusdi, 2024; Widiarini et al., 2025). This condition was also observed in the Mamasa Regency. One of the leading schools in this area, SMAN 1 Mamasa, is highly committed to improving the quality of learning, including physics. Nevertheless, initial observations and discussions with the school indicate that physics learning is still conducted conventionally, with very limited practical activities owing to the scarcity of laboratory equipment. Many experiment-based practices have been replaced with written assignments or simple demonstrations. Based on interviews with physics teachers, there is an urgent need for alternative learning media that can provide virtual experimental experiences for students. This need also aligns with the learning achievement standards at the secondary education level, which require students to select and use digital technology to systematically and accurately collect and record data (Kemendikdasmen, 2025). This underscores the urgency of community service in this school, as it reflects a broader issue faced by many schools in the region: insufficient laboratory resources that hinder meaningful physics learning. Therefore, SMAN 1 Mamasa was chosen as the partner for introducing and mentoring the use of virtual labs.

The development of information technology has fundamentally transformed the landscape of science learning (Gizaw & Tessema, 2020; Goyal & Goyal, 2020; Kadeeva et al., 2022), including the virtual laboratory. Virtual labs allow students to manipulate parameters, collect real-time data, and test conceptual models without requiring expensive physical laboratory equipment or special conditions (Rassudov & Korunets, 2022; Shetty et al., 2020). Recent studies have shown that virtual labs not only maintain cognitive learning outcomes but also impact metacognitive aspects, such as self-regulation and learning motivation, when designed and integrated pedagogically (Al-Duhani et al., 2024; Sapriati et al., 2023). Nevertheless, some studies emphasize that virtual labs are less effective in developing psychomotor and hands-on skills, which remain crucial in physics experimentation (Ching-Pong Poo et al., 2023; Yang et al., 2024). Therefore, virtual labs should be viewed as complementary tools to strengthen the cognitive and motivational aspects of learning, while physical labs continue to play a central role in cultivating practical skills.

A virtual laboratory is an interactive environment that allows students to conduct simulated experiments as part of their learning (Stahre Wästberg et al., 2019). Its relevance becomes clear in schools with limited infrastructure, where hands-on laboratories are difficult to establish and maintain (El Kharki et al., 2021). Compared to alternatives such as mobile labs or low-cost physical kits, virtual labs are more feasible because they are scalable, require no recurring material costs, and can be accessed repeatedly without resource constraints. While physical labs remain essential for psychomotor skill development (Maulidah & Prima, 2018), virtual labs offer a sustainable solution for enhancing conceptual understanding and engagement in resource-constrained environments.

Recent research has confirmed that virtual labs can be an innovative solution to overcome the constraints of physical laboratory infrastructure (Nurlina et al., 2025). A systematic review showed that the implementation of virtual labs in physics education over the last six years has varied in terms of subject matter, educational level, type of virtual laboratory, and targeted thinking skills, highlighting their potential to foster creativity, problem-solving, and critical thinking (Darman et al., 2024). In chemistry education, virtual labs have been shown to significantly improve students' academic performance compared to lecture-only instruction, with effectiveness comparable to real labs, indicating their role as a viable alternative when resources are limited (Bazie et al., 2024). In engineering education, virtual labs have the strongest impact on student learning motivation and engagement, confirming their value as an indispensable auxiliary tool in experimental learning (Li & Liang, 2024). Beyond content mastery, virtual labs also support self-regulated learning (SLR) and positively influence cognitive, metacognitive, and motivational strategies, enhancing students' capacity to manage their learning process (Estoque Loñez & Errabo, 2022; Reginald, 2023; Sapriati et al., 2023).

In practical implementation, *The Physics Aviary* (TPA) is a virtual simulation and laboratory platform offering dozens of interactive physics experiments. This platform enables students to perform measurements, analyze data, and compare virtual experiment results with physics theories. The advantages of TPA include free access, an intuitive interface, and usage without the need for additional software installation (McCulley, n.d.). These features make it ideal for schools with limited physical laboratory facilities.

Based on this potential, this community service activity was designed as training on the use of the TPA virtual laboratory for the students at SMAN 1 Mamasa. The goal is to foster simulation-based experimental experience. This training is expected to provide an engaging and meaningful physics learning solution that enhances students' ability to manage their learning process independently, while strengthening their interest in science education. This study contributes to the development of literature on technology-supported physics learning, particularly in contexts with limited laboratory resources, and offers a novel approach by implementing a virtual laboratory specifically tailored for high school students in Mamasa.

This activity is closely linked to national and global policies. Globally, it supports Sustainable Development Goals (SDGs) Goal 4 on Quality Education, particularly Target 4.4, which focuses on improving information and communication technology skills among youth (Alisjahbana & Murniningtyas, 2018). Nationally, it aligns with Higher Education Key Performance Indicators (IKU), especially IKU 3 (students gain off-campus experience) and IKU 6 (lecturers engage in off-campus activities) by involving university students as mentors in the training (Dirjendikti, 2021). Moreover, it supports Asta Cita point 5, which aims to improve the quality of human life in Indonesia through education (Subianto & Raka, 2023), and is consistent with the National Research Master Plan (RIRN) in the education sector, especially the development of learning models based on information and communication technology.

Thus, this community service activity has two main outcomes. First, a direct contribution to the partner school by enhancing the capacity of teachers and students to utilise educational technology for physics learning. Second, this study contributes to the literature on the effectiveness of virtual labs in developing digital literacy, learning motivation, and SRL at the secondary education level. The integration of community service and research is expected to provide practical recommendations for teachers, principals, and education policymakers regarding effective strategies for implementing virtual labs in schools with limited physical facilities.

## 2 Method

This study is part of a Community Service (PkM) activity designed as training and mentoring on the use of the TPA virtual laboratory for eleventh-grade students at SMAN 1 Mamasa. The approach used in this activity was Community-Based Research (CBR) (Hacker, 2013; Israel et al., 1998), which emphasises collaboration between the research team and the community to address shared learning needs. This activity also integrates elements of Service Learning, where students actively participate in meaningful learning experiences while contributing to the community. Through this approach, students act not only as beneficiaries but also as partners, engaging in exploration, discussion, and reflection on virtual laboratory activities.

The study involved 34 eleventh-grade students (20 females and 14 males), and the objective was to implement the TPA virtual laboratory as an alternative medium for physics learning. The PkM was conducted from July to August of 2025. As this activity focused on tool usability mentoring, it is important to note that research on the use of the TPA virtual laboratory is still very limited, and to the best of our knowledge, no studies in Indonesia have specifically examined its implementation in physics learning. Therefore, this program served as both usability mentoring and the first introduction of the platform in a local school context.

A total of 34 students filled out the questionnaire on learning motivation and SRL, selected using purposive sampling based on the physics material covered in the training module and recommendations from the subject teacher. Figure 1 illustrates the relationship between limited practical experience, low student motivation, and SRL, alongside the proposed solution through direct mentoring in the use of the TPA virtual laboratory.

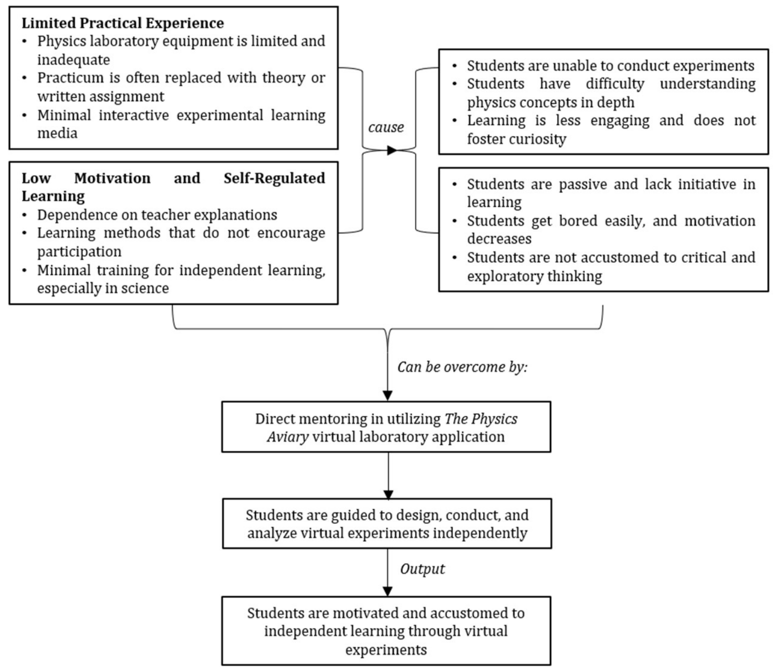


Figure 1. Problem Identification and Solution Flowchart for TPA Virtual Laboratory Training

The activity was conducted in three phases: preparation, implementation, and evaluation, in line with CBR, which emphasises collaborative partnership, community relevance, and co-learning (Hacker, 2013; Israel et al., 1998). The workflow is illustrated in Figure 2.

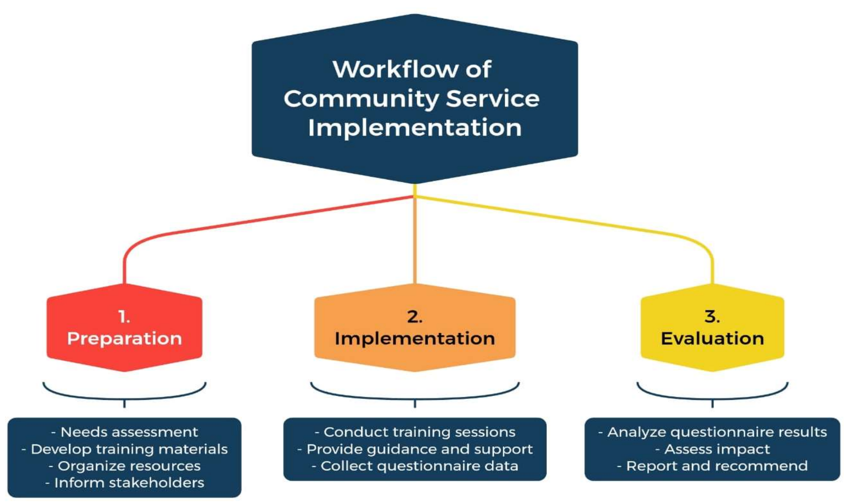


Figure 2. Workflow of Community Service Implementation

In the preparation phase, the team developed web-based virtual laboratory exploration modules and evaluation instruments, including motivation and SRL questionnaires adapted from the Motivated Strategies for Learning Questionnaire (MSLQ) (Nurlina et al., 2025; Pintrich & De Groot, 1990; Wang et al., 2023), which were modified to suit the context of virtual laboratory-based experiments. All instruments were validated by three experts to ensure their content validity and measurement reliability. The indicators of learning motivation and SRL are listed in the Appendix.

The implementation phase began with interactive training on using the TPA virtual laboratory, accompanied by practical training. Students were guided to explore physics simulation experiments both independently and in groups and were encouraged to discuss and reflect on their exploration results. Upon completing all training sessions, the students completed the motivation and SRL questionnaires.

The final phase involved evaluating the data obtained from both instruments. The questionnaires were analysed using descriptive quantitative methods by calculating the mean scores, standard deviations, and percentage distributions on a five-point Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral/Don’t Know, 4 = Agree, 5 = Strongly Agree) (Gay et al., 2012). The percentage analysis results were used to assess the impact of training on students’ learning motivation and SRL. All activities were carried out with school approval, maintaining data confidentiality, and adhering to the ethical principles of research and community service.

## 3 Results

The community service activity, consisting of training and mentoring on the use of the TPA virtual laboratory, was conducted with 34 eleventh-grade students from SMAN 1 Mamasa, comprising 20 females and 14 males. During the implementation phase, the students received training on how to access the application, log in, and directly run physics experiment simulations using the platform. Intensive mentoring was also provided to ensure that students could operate the application independently and understand the learning concepts presented through virtual simulations. Figure 3 illustrates the training and mentoring activities, showing students' enthusiasm and active involvement.

Figure 3. Implementation Activities of Using the TPA Virtual Laboratory in Class

Table 1 presents students' learning motivation and SRL when using *The Physics Aviary*. Learning motivation scores varied between high and moderately high categories. The highest average motivation indicator was intrinsic goal orientation (A1), with a mean of 4.12, followed by task value (A3) at 4.06 and control of learning beliefs (A4). This indicates that students were primarily driven by interest, enjoyment, and perceived benefits of the virtual experiments, as well as a belief that their learning success depended on their efforts. In contrast, extrinsic goal orientation (A2) scored the lowest at 3.68, suggesting that external rewards or recognition were not the main motivators for using the virtual lab.

Table 1. Descriptive Statistics of Students' Motivation and SRL in Using TPA Virtual Laboratory

| Indicator | Item | Mean | Std. Deviation | Cronbach's Alpha |
|---|---|---|---|---|
| Learning Motivation | | | | |
| A1. Intrinsic Goal Orientation | A11-A15 | 4.1176 | 0.94595 | 0.93 |
| A2. Extrinsic Goal Orientation | A21-A25 | 3.6765 | 0.91189 | 0.81 |
| A3. Task Value | A31-A35 | 4.0588 | 0.88561 | 0.92 |
| A4. Control of Learning Beliefs | A41-A45 | 4.0294 | 0.90404 | 0.87 |
| A5. Self-Efficacy for Learning and Performance | A51-A55 | 3.9412 | 0.77621 | 0.87 |
| Self-Regulated Learning (SRL) | | | | |
| B1. Metacognitive Self-Regulation | B11-B15 | 3.7647 | 0.95533 | 0.91 |
| B2. Effort Regulation | B21-B25 | 3.8824 | 0.91336 | 0.96 |
| B3. Time and Study Environment Management | B31-B34 | 4.0588 | 0.81431 | 0.93 |
| B4. Peer Learning | B41-B44 | 3.9118 | 0.99598 | 0.95 |
| B5. Help Seeking | B51-B55 | 3.8824 | 0.97746 | 0.96 |

In terms of SRL, the highest average score was in time and study environment management (B3) at 4.06, followed by effort regulation (B2) and help-seeking (B5), both at 3.88. These findings confirm that students were fairly capable of managing their study schedules, maintaining conducive learning environments, and persevering through challenges. Meanwhile, metacognitive self-regulation (B1) scored the lowest at 3.76, indicating a need to strengthen students' planning, monitoring, and self-evaluation strategies during virtual experimentation.

All motivation and SRL indicators demonstrated high to very high internal consistency, with Cronbach's alpha values ranging from 0.81 to 0.96. Overall, these results suggest that TPA effectively fosters strong intrinsic motivation and supports the development of students' self-regulation skills in technology-based learning environments.

Figure 4 shows the analysis results of the students' responses to the learning motivation questionnaire. The results revealed positive trends across various motivational dimensions. For intrinsic goal orientation, most students expressed happiness and satisfaction in understanding physics concepts through the virtual laboratory, with 91.18% agreeing or strongly agreeing that they felt joyful and satisfied after completing the experiments. Additionally, 67.65% were motivated to deepen their physics understanding via virtual experiments, and 73.53% completed practical work because they enjoyed the learning process facilitated by the platform. Interest in observed physics phenomena was also very high (94.11%), confirming that the virtual laboratory effectively nurtured intrinsic motivation.

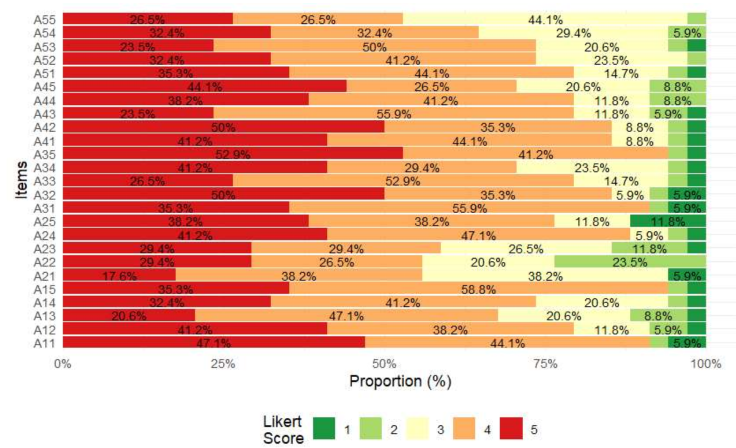


Figure 4. Percentage Distribution of Student Responses for Each Item in the Learning Motivation Questionnaire

Student motivation was more varied regarding extrinsic goal orientation. About 55.89% completed the practical work aiming for high grades, while motivation related to grades affecting report cards and parental/teacher expectations was 55.88% and 58.82%, respectively. Nevertheless, 85.3% of the students participated in the practical activities to understand the material content rather than out of obligation, and 76.48% showed increased enthusiasm when rewarded or recognised by teachers or schools. This indicates that extrinsic motivation exists but is not the dominant driver for students' learning.

In the task value dimension, students showed a strong belief that virtual laboratory experiments helped them understand physics material (91.17%), and 85.29% believed that the experience would benefit their future. Most students (79.41%) considered virtual experiments to be as important as hands-on practice, and 70.59% viewed the virtual laboratory as an effective and valuable learning method. These findings indicate that students perceive both intrinsic and utility values when engaging in virtual experiments. According to expectancy-value theory, learners' motivation is influenced by the value they assign to a task and their expectations of success (Wigfield & Eccles, 2000). In this context, students' high task value ratings suggest that the TPA virtual laboratory effectively enhances motivation by demonstrating the relevance and usefulness of virtual experiments, which aligns with prior research on technology-enhanced learning environments (Darman et al., 2024; Estriegana et al., 2019).

Control of learning beliefs also received strong responses, with 85.3% believing their effort in virtual experiments helped their understanding, and 85.29% confident that hard work would lead to concept mastery. More than 79% independently addressed difficulties encountered in the virtual laboratory, and 79.42% felt that their learning outcomes depended on their effort. Awareness of personal responsibility was also evident, with 70.59% stating that understanding the virtual laboratory was their responsibility. This high level of learning control may be influenced by the characteristics of the students at SMAN 1 Mamasa, such as their strong intrinsic motivation, prior familiarity with digital tools, and access to technology that supports independent exploration. These contextual factors likely contributed to students' proactive engagement and self-regulation during virtual laboratory activities, suggesting that both individual and environmental characteristics play a role in shaping self-directed learning behaviour (Pintrich, 2000; Zimmerman, 2015).

In the self-efficacy dimension, most students were confident in understanding physics through the virtual laboratory (79.41%) and completing tasks effectively (73.53%). They also felt confident using the virtual laboratory (73.53%) and were able to perform experiments without significant difficulty (64.7%). These results align with previous studies showing that virtual labs can enhance students' self-efficacy in science learning (Adanir et al., 2022; Gungor et al., 2022). However, confidence in explaining experimental results to peers showed variability, with approximately 52.94% confident and the rest unsure or less confident, indicating an area for improvement to support communication and collaborative learning.

Figure 5 illustrates the responses to the SRL questionnaire across several dimensions: metacognitive regulation, effort regulation, time and environment management, peer learning, and help-seeking. In metacognitive regulation, most students demonstrated adequate awareness of their learning processes. Approximately 58.82% of the students planned carefully before the experiments, 67.65% read and tried to understand the experiment objectives, 64.7% checked their understanding during the experiments, and 61.76% sought alternative learning methods, such as videos or peer help, when facing difficulties. After the experiment, 70.59% evaluated their understanding, reflecting satisfactory metacognitive awareness despite 26-29% of respondents still being uncertain ("Don't Know"), indicating the presence of a subgroup that while the majority actively engaged in self-regulated learning, targeted support and guidance may be needed to help all students develop stronger planning, monitoring, and evaluation skills, consistent with findings in previous studies on SRL in virtual laboratory environments (Al-Duhani et al., 2024).

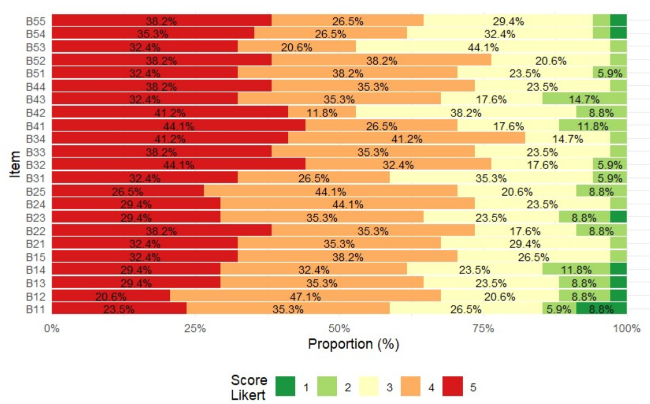


Figure 5. Percentage Distribution of Student Responses for Each Item in the SRL Questionnaire

In effort regulation, students demonstrated considerable perseverance. Most students (67.64%) continued trying to understand the material despite difficulties, and 73.53% did not easily give up. Seriousness in completing tasks was reflected by 73.53% who worked diligently, and 70.59% who tried again if they failed. Nevertheless, some students showed uncertainty about their ability to maintain effort (noted by "Don't Know" responses).

Regarding time and study environment management, students generally managed their time and learning environments well. Approximately 58.82% scheduled specific times for practical work, 76.47% sought comfortable, distraction-free study spaces, and 73.52% ensured sufficient time and minimised disruptions during experiments, indicating readiness to manage time and conditions.

Peer learning showed a moderate role in social interaction. Approximately 70.59% discussed experiments with peers, 67.64% frequently exchanged opinions, and 73.53% often collaborated on tasks. However, about 38% responded “Don’t Know” to some items, indicating that not all students were actively engaged in collaborative learning.

Finally, in help-seeking, students demonstrated a good willingness to ask for help when needed. Approximately 70.59% asked teachers without hesitation, and 76.48% sought peer assistance when unclear about results. However, the initiative to seek additional learning resources, such as books or videos, was lower, with only 53% of the students agreeing. Students felt comfortable seeking guidance from teachers, peers, or seniors (61.76%), and most (64.71%) preferred trying independently before asking for help, showing a balance between independence and collaboration in their learning approach.

Overall, these findings indicate that the TPA virtual laboratory supports student SRL by enhancing metacognitive regulation, effort management, time management, social interaction, and help-seeking behaviour. However, there remains room for development, particularly in strengthening collaborative activities and encouraging proactive seeking of additional learning resources to optimise student autonomy in the learning process.

Figure 6 presents the percentage distribution of student satisfaction questionnaire responses regarding training using *The Physics Aviary*. Most respondents gave high scores for the relevance and benefits of the material (C1, C2), ease of understanding and clarity of delivery (C3, C4), and enjoyable atmosphere of the activities (C7). Student engagement (C5) and allocated discussion time (C7) were also well appreciated, while motivation (C6), SRL (C9), and overall satisfaction (C10) received positive but slightly lower evaluations. In general, the training successfully met students’ needs and effectively supported learning.

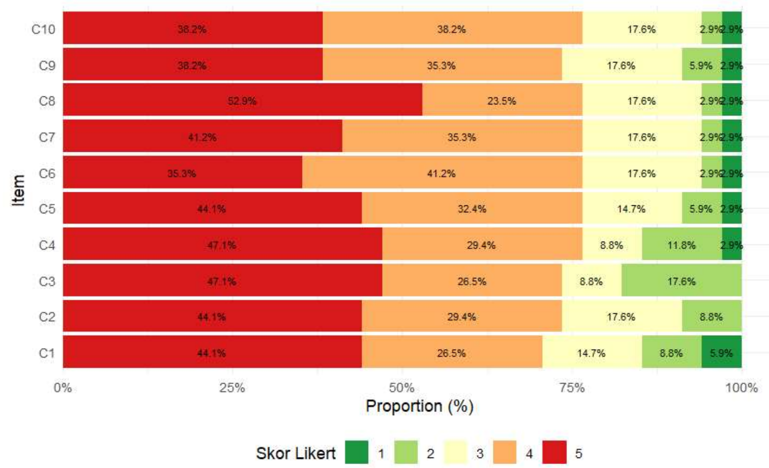


Figure 6. Percentage Distribution of Student Responses for Each Item in the Satisfaction Questionnaire Regarding Use of TPA Virtual Laboratory

Although the study did not apply a pre-test and post-test design, the results of the questionnaires and observations during implementation indicated positive behavioural tendencies after the service. Students demonstrated greater enjoyment and persistence in learning, improved their ability to manage their time and study environments, and actively sought help when facing difficulties. In addition, the high level of student satisfaction reflected increased confidence and engagement in using the virtual lab. These findings suggest that the service activity not only enhanced students' motivation and SRL scores but also translated into observable behavioural changes in their learning practices during the semester.

## 4 Discussion

The implementation of training and mentoring in using the TPA virtual laboratory with eleventh-grade students at SMAN 1 Mamasa demonstrated success in fostering active student engagement and participation throughout the learning process. The enthusiasm observed during the implementation phase indicates that virtual labs can serve as an engaging learning medium that motivates students to understand physics concepts interactively.

The measured learning motivation in this study was dominated by intrinsic motivation, particularly intrinsic goal orientation, which received the highest average score (4.12). This suggests that students were driven by curiosity, enjoyment, and the perceived usefulness of virtual practicums in supporting their understanding of physics. This phenomenon aligns with intrinsic motivation theory, which emphasises that motivation arising from within the student, such as interest and learning satisfaction, is a primary driver of sustained engagement and academic success (Firdaus et al., 2023; Hamed & Aljanazrah, 2020; Sumarno, 2021).

In contrast, extrinsic motivation scored lower, indicating that external rewards, such as grades or recognition, were not the main factors influencing the use of this virtual laboratory. This tendency may also reflect the broader learning culture in Indonesian schools, where assessment systems often focus on written examinations rather than practical performance. As a result, students may place less emphasis on external incentives in experimental contexts and value the interactive and enjoyable aspects of learning. These findings suggest that technology-based learning media are particularly effective in fostering intrinsic rather than extrinsic motivation.

Furthermore, the SRL aspect also showed positive results with high scores in time and study environment management (4.06), as well as effort regulation and help-seeking abilities. Among these, time and study environment management were the most relevant to the virtual laboratory context, as students needed to independently schedule and organise their learning when accessing and experimenting with the simulations. The ability to regulate effort and seek help also played important roles, as students needed persistence to repeat simulations and relied on peers or teachers when encountering difficulties. This reflects students' capability to independently plan, manage, and regulate their learning processes, consistent with SRL concepts that emphasise active student roles in planning, executing, and evaluating learning (Zimmerman, 2015). However, the lowest score in metacognitive regulation (3.76) highlights the need for increased focus on developing students' strategies for planning, monitoring, and self-evaluation when using virtual laboratories.

Compared to conventional methods, such as lecture-based instruction or limited hands-on laboratory work, virtual labs show clear advantages. For instance, a meta-analysis in engineering education found that virtual labs significantly increased student motivation and engagement compared with traditional laboratory settings (Li & Liang, 2024). Similarly, a systematic review of SRL found that students using virtual labs outperformed their peers in traditional classroom settings in aspects of self-regulated learning (Sapriati et al., 2023).

The analysis of the learning motivation dimensions reinforces *that* TPA effectively fosters students' interest and confidence in learning physics through virtual simulation. The high percentage of students who felt satisfied and happy with this method, as well as those who believed their efforts contributed to learning success, indicates the media's success in integrating cognitive and affective learning aspects. These findings are consistent with the literature, emphasising the importance of task value and control of learning beliefs in supporting motivation and academic performance (Pintrich & De Groot, 1990; Umarji et al., 2021, 2023).

Regarding SRL, students' learning independence is evident from their ability to manage time, environment, and effort, along with persistence in the face of difficulties. However, some uncertainty in effort regulation and social collaboration items suggests room for improvement, particularly in facilitating collaboration and encouraging the proactive seeking of additional learning resources.

Lastly, student satisfaction with the virtual laboratory training was generally high, especially concerning material relevance, ease of use, and a pleasant learning atmosphere. This indicates that the training effectively met the students' learning needs and supported optimal media use. User satisfaction is a critical indicator of successful learning technology implementation and positively influences motivation and performance.

Overall, these findings confirm that the TPA virtual laboratory functions not only as an effective learning tool but also as a medium that fosters intrinsic motivation and self-regulation. However, further enhancement of metacognitive aspects and collaborative learning should be prioritised to fully maximise the potential of technology-based learning. Future recommendations include strengthening data analysis and collaboration features in the design of virtual laboratory learning experiences.

## 5 Conclusion

The training on the use of the TPA virtual laboratory conducted for students at SMAN 1 Mamasa proved effective in fostering learning motivation, particularly intrinsic motivation, as well as students' learning independence within the context of physics education. Through interactive mentoring and training, students were able to optimise their use of virtual media to manage their study time, regulate effort, and seek help independently. The high level of student satisfaction with the training indicates the successful implementation of the virtual laboratory as a relevant and engaging learning tool. However, further enhancement is needed in metacognitive regulation and collaborative activities to ensure the comprehensive development of learning independence. Future recommendations include integrating learning strategies that emphasise metacognitive reflection and student collaboration in the use of virtual labs to maximise the benefits of this technology for improving the quality of physics learning in secondary schools.

## 6 Acknowledgment

The author would like to express sincere gratitude to the Head of SMAN 1 Mamasa, the teachers, and the participating students for their active cooperation and enthusiasm during the implementation of this community service project. Special thanks are extended to the student team members who provided valuable assistance and dedication throughout the activity. This program was funded by the DIPA Grant of Universitas Sulawesi Barat in 2025, under the Partnership Service scheme.

## 7 Reference

Adanir, G. A., Akmatbekova, A., & Muhametjanova, G. (2022). University Learners' Motivation and Experiences in Using Virtual Labs in a Physics Course/Motivation et expériences des apprenants universitaires dans l'utilisation de laboratoires virtuels dans un cours de physique. *Canadian Journal of Learning & Technology*, *48*(2), 1–15. https://search.ebscohost.com/login.aspx?direct=true&db=ehh&AN=161429662&site=ehost-live https://doi.org/10.21432/cjlt28161

Al-Duhani, F., Saat, R. M., & Abdullah, M. N. S. (2024). Effectiveness of web-based virtual laboratory on grade eight students' self-regulated learning. *Eurasia Journal of Mathematics, Science & Technology Education*, *20*(3), 1–20. https://doi.org/10.29333/ejmste/14282

Alisjahbana, A. S., & Murniningtyas, E. (2018). *Tujuan pembangunan berkelanjutan di Indonesia : konsep, target, dan strategi implementasi*. Unpad Press.

Bazie, H., Lemma, B., Workneh, A., & Estifanos, A. (2024). The Effect of Virtual Labs on the Academic Achievement of Undergraduate Chemistry Students: Quasi-Experimental Study. *JMIR Formative Research*, *8*. https://doi.org/10.2196/64476

Ching-Pong Poo, M., Lau, Y., & Chen, Q. (2023). *Are Virtual Labs and Remote Labs Enhancing the Quality of Sustainability Education?* https://doi.org/10.3390/educsci

Darman, D. R., Suhandi, A., Kaniawati, I., Samsudin, A., & Wibowo, F. C. (2024). Virtual laboratory in physics education: A systematic review. *AIP Conference Proceedings*, *3116*(1), 40008. https://doi.org/10.1063/5.0210640

Dirjendikti. (2021). *Buku Panduan Indikator Kinerja Utama Perguruan Tinggi Negeri*. Kementerian Pendidikan dan Kebudayaan.

El Kharki, K., Berrada, K., & Burgos, D. (2021). Design and implementation of a virtual laboratory for physics subjects in moroccan universities.

*Sustainability (Switzerland)*, *13*(7). https://doi.org/10.3390/su13073711

Estoque Loñez, H., & Errabo, D. D. (2022). Students' Self-Motivation, Self-Efficacy, Self-Regulation in Virtual Laboratory in Human Anatomy Subject. *Proceedings of the 2022 13th International Conference on E-Education, E-Business, E-Management, and E-Learning*, 30–34. https://doi.org/10.1145/3514262.3514312

Estriegana, R., Medina-Merodio, J.-A., & Barchino, R. (2019). Student acceptance of virtual laboratory and practical work: An extension of the technology acceptance model. *Computers & Education*, *135*, 1–14. https://doi.org/https://doi.org/10.1016/j.compedu.2019.02.010

Firdaus, T., Sinensis, A. R., & Effendi. (2023). Virtual Laboratory in Physics Education: Penguasaan Konsep Mahasiswa dalam Mata Kuliah Fisika Inti. *JIPFRI (Jurnal Inovasi Pendidikan Fisika Dan Riset Ilmiah)*, *7*(1), 40–45. https://doi.org/10.30599/jipfri.v7i1.2234

Gay, L., Mills, G. E., & Airasian, P. (2012). *Educational Research: Competencies for Analysis and Applications* (10th Edition). Pearson.

Gizaw, M. E., & Tessema, G. W. (2020). Role of information and communication technologies in educational systems: a systematic review. *International Journal of Scientific Reports*, *6*(7), 277. https://doi.org/10.18203/issn.2454-2156.intjscirep20202644

Goyal, D., & Goyal, N. (2020). *Role of Information and Communication Technologies in Transforming Teaching and Learning Environments* (pp. 1–12). https://doi.org/10.4018/978-1-7998-0010-1.ch001

Gungor, A., Kool, D., Lee, M., Avraamidou, L., Eisink, N., Albada, B., van der Kolk, K., Tromp, M., & Bitter, J. H. (2022). The Use of Virtual Reality in A Chemistry Lab and Its Impact on Students' SelfEfficacy, Interest, Self-Concept and Laboratory Anxiety. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(3). https://doi.org/10.29333/ejmste/11814

Hacker, K. (2013). *Community-Based Participatory Research*. SAGE

Publications, Inc. https://doi.org/10.4135/9781452244181

Hamed, G., & Aljanazrah, A. (2020). the Effectiveness of Using Virtual Experiments on Students' Learning in the General Physics Lab. *Journal of Information Technology Education: Research*, *19*, 977–996. https://doi.org/10.28945/4668

Humairah, N. A., Sartika, D., & Nurlina, N. (2023). Pelatihan Keterampilan Proses Sains Peserta Didik SMAN 2 Campalagian melalui Kegiatan Pembimbingan Praktikum Fisika. *JAST : Jurnal Aplikasi Sains Dan Teknologi*, *7*(2), 192–203. https://doi.org/https://doi.org/10.33366/jast.v7i2.5370

Israel, B. A., Schulz, A. J., Parker, E. A., & Becker, A. B. (1998). Review of community-based research: Assessing partnership approaches to improve public health. *Annual Review of Public Health*, *19*, 173–202. https://doi.org/10.1146/annurev.publhealth.19.1.173

Kadeeva, O., Belov, A., Repsh, N., Berseneva, S., & Grevtsov, K. (2022). Information and communication technologies in teaching Biology in the context of distance learning. *Vestnik of Kostroma State University. Series: Pedagogy. Psychology. Sociokinetics*, *27*, 312–316. https://doi.org/10.34216/2073-1426-2021-27-4-312-316

Kemendikdasmen. (2025). *Salinan Keputusan Kepala Badan Standar, Kurikulum, dan Asesmen Pendidikan Nomor 046/H/KR/2025 tentang Capaian Pembelajaran pada Pendidikan Anak Usia Dini, Jenjang Pendidikan Dasar, dan Jenjang Pendidikan Menengah*. Kemendikdasmen.

Li, J., & Liang, W. (2024). Effectiveness of virtual laboratory in engineering education: A meta-analysis. *PLoS ONE*, *19*(12), 1–23. https://doi.org/10.1371/journal.pone.0316269

Maulidah, S. S., & Prima, E. C. (2018). Using Physics Education Technology as Virtual Laboratory in Learning Waves and Sounds. *Journal of Science Learning*, *1*(3), 116. https://doi.org/10.17509/jsl.v1i3.11797

McCulley, F. (n.d.). *The Physics Aviary*. Www.Thephysicsaviary.Com. Retrieved August 8, 2025, from https://thephysicsaviary.com/

Miškář, D. (2019). Physics experiment as a dominant educational element. *AIP Conference Proceedings*, *2152*(1), 30024. https://doi.org/10.1063/1.5124768

Nurlina, N., Musdar, M., Hajati, K., & Zulfiani, U. (2024). *STEM-Based Physics Modules with CK-12 Simulations for High School Students : Development and Implementation*. *10*(2), 395–408.

Nurlina, N., Rahmadhani, A., Rahman, I., Arsyad, A. A., & Kalsum, U. (2025). Analyzing the Motivation and Self-Regulated Learning of Prospective Physics Teachers in Virtual Laboratory-Based Fundamental Physics Experiments. *Jurnal Penelitian Pendidikan IPA*, *11*(5), 692–701. https://doi.org/10.29303/jppipa.v11i5.11117

Pintrich, P. R. (2000). Chapter 14 - The Role of Goal Orientation in Self-Regulated Learning. In *Handbook of Self-Regulation* (pp. 451–502). Academic Press. https://doi.org/10.1016/B978-012109890-2/50043-3

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33–40. https://doi.org/10.1037/0022-0663.82.1.33

Rassudov, L., & Korunets, A. (2022). Virtual Labs: an Effective Engineering Education Tool for Remote Learning and not only. *2022 29th International Workshop on Electric Drives: Advances in Power Electronics for Electric Drives (IWED)*, 1–4. https://doi.org/10.1109/IWED54598.2022.9722375

Reginald, G. (2023). Teaching and learning using virtual labs: Investigating the effects on students' self-regulation. In *Cogent Education* (Vol. 10, Issue 1). Taylor and Francis Ltd. https://doi.org/10.1080/2331186X.2023.2172308

Rusdi, I. sari. (2024). Strategies Of Elementary School Teachers To Teach Practicum-Based Science In The Midst Of Limited Laboratory Facilities. *SEARCH: Science Education Research Journal*, *3*(1), 26–35. https://doi.org/10.47945/search.v3i1.1503

Sapriati, A., Suhandoko, A. D. J., Yundayani, A., Karim, R. A., Kusmawan, U., Mohd Adnan, A. H., & Suhandoko, A. A. (2023). The Effect of Virtual Labs on Improving Students' SRL: An Umbrella Systematic Review. In *Education Sciences* (Vol. 13, Issue 3). MDPI. https://doi.org/10.3390/educsci13030222

Shetty, S., Shetty, A., Aishwarya Hegde, A., Salian, A. B., Akshaya, Umesh, P., & Gangadharan, K. V. (2020). Experiential Learning of Physio-Chemical and Bacteriological Properties of Water using Virtual Labs. *2020 IEEE International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics, DISCOVER 2020 - Proceedings*, *August 2021*, 273–278. https://doi.org/10.1109/DISCOVER50404.2020.9278043

Stahre Wästberg, B., Eriksson, T., Karlsson, G., Sunnerstam, M., Axelsson, M., & Billger, M. (2019). Design considerations for virtual labs: A comparative study of two virtual labs for learning about gas solubility and colour appearance. *Education and Information Technologies*, *24*(3), 2059–2080. https://doi.org/10.1007/s10639-018-09857-0

Subianto, P., & Raka, G. R. (2023). *Asta Cita: Visi dan Misi Prabowo-Gibran*.

Sumarno, W. B. H. (2021). Meretas Motivasi Belajar Peserta Didik Di Era Pandemi Melalui Video Virtual Laboratory. *Wawasan: Jurnal Kediklatan Balai Diklat Keagamaan Jakarta*, *2*(1), 33–39. https://doi.org/10.53800/wawasan.v2i1.71

Umarji, O., McPartlan, P., Moeller, J., Li, Q., Shaffer, J., & Eccles, J. (2021). The motivational system of task values and anticipated emotions in daily academic behavior. *Motivation and Emotion*, *45*(5), 599–616. https://doi.org/10.1007/s11031-021-09898-y

Umarji, O., Wan, S., Wolff, F., & Eccles, J. (2023). The system of academic task values: The development of cross-domain comparisons of values and college major choice. *Developmental Psychology*, *59*(6), 1032.

Wang, F., Jiang, C., King, R. B., & Leung, S. O. (2023). Motivated Strategies for Learning Questionnaire (MSLQ): Adaptation, validation, and development of a short form in the Chinese context for mathematics. *Psychology in the Schools*, *60*(6), 2018–2040. https://doi.org/10.1002/pits.22845

Widiarini, P., Rapi, N. K., Suastra, I. W., & Suma, K. (2025). Studi Pendahuluan: Problematika Pembelajaran Fisika Sma. *SCIENCE : Jurnal Inovasi Pendidikan Matematika Dan IPA*, *5*(1), 131–143. https://doi.org/10.51878/science.v5i1.4430

Wigfield, A., & Eccles, J. S. (2000). Expectancy–Value Theory of Achievement Motivation. *Contemporary Educational Psychology*, *25*(1), 68–81. https://doi.org/https://doi.org/10.1006/ceps.1999.1015

Yang, C., Zhang, J., Hu, Y., Yang, X., Chen, M., Shan, M., & Li, L. (2024). The impact of virtual reality on practical skills for students in science and engineering education: a meta-analysis. *International Journal of STEM Education*, *11*(1). https://doi.org/10.1186/s40594-024-00487-2

Zimmerman, B. (2015). Self-Regulated Learning: Theories, Measures, and Outcomes. *International Encyclopedia of the Social & Behavioral Sciences*. https://doi.org/10.1016/B978-0-08-097086-8.26060-1