International Journal of Learning Spaces Studies, 2025. 3(2): 66-79.

The International Journal of Learning Spaces Studies (IJLSS)

Homepage: https://journals.artahub.com/

ORIGINAL RESEARCH ARTICLE

Evaluation of the Success of the "Ata Virtual Science Laboratory" Based on Everett Rogers' Innovation Diffusion Model

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ARTICLE INFO

Article History:
Received: 2025-01-07
Revised: 2025-02-16
Accepted: 2025-02-25
Published Online: 2025-06-01

Keywords:
Virtual Laboratory; Evaluation; Innovation; Everett Rogers' Innovation Diffusion Theory

Number of Reference: 23
Number of Figures: 0
Number of Tables: 6

DOI:

10.22034/lss.2025.498598.1032

ABSTRACT

This study aims to elucidate the necessity of utilizing the "Ata Virtual Science Laboratory" in elementary science education and to assess the performance of this simulated software. As the first virtual laboratory in Iran, alongside the limited availability of simulation software, this innovation plays a crucial role in deepening and accelerating the learning of experimental aspects in elementary science curricula. Therefore, evaluating this technological and innovative program from various dimensions—including infrastructure readiness, public acceptance, user-friendliness, compatibility, and relative advantage—is imperative. Accordingly, the objective of this research is to assess the success or failure of the "Ata Virtual Science Laboratory" based on the criteria of innovation diffusion. The theoretical and practical framework selected for this study is Everett Rogers' globally recognized Innovation Diffusion Theory. The five key criteria of this model (relative advantage, compatibility, complexity, trialability, and observability) provide a comprehensive foundation for evaluating any innovation. For data analysis, an independent t-test and statistical techniques (descriptive and inferential) were employed. The results indicate that, from the teachers' perspective, the Ata Virtual Science Laboratory aligns with the five attributes of Rogers' theory. The level of alignment or success of all components was above average and statistically significant. Finally, research limitations were discussed, and practical and research-based recommendations were provided for future studies. ©**authors**

►**Citation:** Shad, M., Hatami, J., & Azimi, E. (2025). Evaluation of the Success of the "Ata Virtual Science Laboratory" Based on Everett Rogers' Innovation Diffusion Model. *The International Journal of Learning Space Studies (IJLSS), 3(1): 66-79. 10.22034/lss.2025.498598.1032*

1. Introduction

In recent years, the field of educational technology has witnessed significant advancements, providing educators and learners with innovative tools and platforms to enhance teaching and learning experiences. The development of information technology has not only transformed lifestyles but has also led to educational reforms (Santos & Prudent, 2021). One such innovation is the virtual laboratory—a simulated environment that replicates real-world laboratory activities, allowing students to engage in hands-on learning experiences without the constraints of time, location, and physical resources (Achuthan et al., 2020). In addition to simulation-based virtual laboratories, another type, known as online (remote) laboratories, has been developed, enabling remote access to laboratory environments via the Internet or intranet (Abdulwahed & Nagai, 2011). Virtual laboratories offer multiple advantages, including increased accessibility, cost-effectiveness, and the ability to provide personalized learning experiences (Wang et al., 2020). Furthermore, virtual laboratories afford unlimited time, immediate feedback, experiment repetition, and safety for students and test subjects (Vasiliadou, 2020). However, some researchers argue that using virtual manipulations in certain areas of science may deprive students of the hands-on experiences that real laboratory interactions provide (Clark, 1994).

As an innovation, virtual laboratories promote a flexible, inclusive, and sustainable approach to enhancing educational knowledge and resources, overcoming common limitations associated with laboratory skill training (Achuthan et al., 2020). However, to maximize their relative advantages over current resources and practices—such as community-based learning environments, updated user interfaces, and new automated assessment mechanisms—continuous adaptations are required. Assessing these adaptations comprehensively is essential to ensuring their effectiveness.

During the early 1970s, in parallel with progressive and innovation-driven nations, Iran also began adopting and expanding educational innovations. Notable examples include the establishment of the Literacy Corps (1962), the recruitment of education experts by the Ministry of Education to explore educational reforms (1964), the creation of a radio station for teacher education, the implementation of mobile libraries for rural areas (1970s), the introduction of shift-based and evening schools to increase enrollment rates (1970s), and the development of correspondence courses for teacher training, particularly for Literacy Corps members in remote villages (1970). Additionally, the founding of Azad University in 1973 marked another significant step (Eman, 1974).

According to Rogers' Innovation Diffusion Theory, the adoption of an innovation follows a five-stage process:

1. **Knowledge** – Individuals are exposed to the innovation and learn about its features and functionality.
2. **Persuasion** – Individuals form a favorable or unfavorable attitude toward the innovation.
3. **Decision** – Individuals decide whether to accept or reject the innovation.
4. **Implementation** – Those who accept the innovation put it into practice.
5. **Confirmation** – Individuals seek to justify their decision by emphasizing the benefits of the innovation. However, if they later receive significant negative feedback about its shortcomings, they may abandon their decision (Rogers, 1995: 27).

Main Research Question

To what extent does the Ata Virtual Science Laboratory align with the five key criteria of Rogers' Diffusion of Innovations Theory from the perspective of elementary school teachers?

Specific Research Questions

1. To what extent does the Ata Virtual Science Laboratory exhibit relative advantage from the perspective of elementary school teachers?

2. To what extent does the Ata Virtual Science Laboratory demonstrate compatibility from the perspective of elementary school teachers?
3. To what extent is the Ata Virtual Science Laboratory characterized by ease of use and comprehensibility from the perspective of elementary school teachers?
4. To what extent does the Ata Virtual Science Laboratory meet the criterion of trialability from the perspective of elementary school teachers?
5. To what extent does the Ata Virtual Science Laboratory fulfill the criterion of observability from the perspective of elementary school teachers?

2. Literature Review

According to Wadiyolu (2006), the adoption of technology is considered the most significant event of the present century. Despite the advantages of virtual laboratories, selecting the appropriate type is not a simple task, as it must align with effective and enhanced learning processes. Case studies and analyses indicate that teacher support (human mediator) and virtual laboratories (educational tool) interact dialectically, which is crucial for achieving successful learning outcomes (Hassan et al., 2022). However, despite their growing popularity and widespread adoption in educational environments, the need for evaluating the overall success and effectiveness of virtual laboratories remains critical. Such evaluations are essential for educational institutions, educators, and policymakers to make informed decisions about integrating and optimizing virtual laboratories in curricula (Achuthan et al., 2020).

To better understand the necessity of evaluating virtual laboratories, it is crucial to examine the significance and challenges of teaching and learning science subjects. According to an initial report from the Iranian Research and Educational Planning Organization on the 2019 TIMSS exam results, Iranian students' average correct response rate to test questions was 20-30% lower than the international average (as cited by the Educational Research and Studies Institute, 2019). Another notable finding was that Iranian students performed better on multiple-choice questions than on open-ended questions, and their responses were more accurate for lower-level knowledge questions than for higher-order learning tasks (reasoning and application) (Sa’adati, 2019). Numerous global studies have examined the challenges of learning science and have concluded that many of these difficulties stem from the methods used to teach science (Sa’adati, 2019).

Tepper (2019) argues that one of the most significant obstacles in science education is the lack of emphasis on it during early childhood and elementary education. Even at the elementary level, science receives less attention compared to subjects like mathematics and literature, leaving students with limited opportunities for foundational scientific exploration. Many teachers lack the necessary knowledge or confidence to engage in scientific discussions and often resort to traditional lecture-based instruction, merely reading from textbooks.

Science education fundamentally relies on concepts, experiments, and observations, which should be integrated into classroom instruction to help students visualize scientific principles. Laboratory activities are a core component of experimental science education, fostering students’ scientific knowledge, skills, and attitudes (Sour et al., 2010). Experts identify four key reasons for incorporating laboratories in science education:

1. Science involves complex and abstract concepts that students—especially in elementary and high school—may struggle to grasp without hands-on experimentation.
2. Engaging in real data collection and analysis instills respect for the scientific process, fostering positive attitudes toward science.
3. Laboratory activities enhance students' practical skills.
4. Students enjoy hands-on science experiments, increasing their interest in the subject (Rainy & Aldila, 2023).

In science classrooms, students learn by constructing and experiencing knowledge firsthand, enabling them to retain and apply what they learn to real-life situations. Practical science courses enhance the quality of learning. While science education traditionally takes place in physical laboratories, advancements in information technology have led to the integration of virtual laboratories. As previously mentioned, virtual laboratories serve as auxiliary tools that facilitate teaching and learning by providing simulation and modeling opportunities. In modern science education, the use of digital simulation software is essential for achieving high-level learning outcomes in interactive and collaborative environments (Durkaya, 2023). Simulations provide dynamic access to multiple representations, making abstract concepts visible, engaging, and enjoyable while enabling safe and rapid experimentation (Lulyarti et al., 2021).

The focus of this study is the evaluation of the Ata Virtual Science Laboratory, Iran’s first virtual science laboratory, developed by the knowledge-based company Ayandeh Amoozan Ata. This technology company, based in Tarbiat Modares University’s Science and Technology Park, successfully completed its incubation and growth phases and was recognized as a leading technology unit in 2016 and 2017. The company assembled an interdisciplinary team, including experts in educational management, instructional technology, educational planning, information science, computer science, graphical simulation, and graphic design, to operationalize the concept of virtual science laboratories. The Ata Virtual Science Laboratory project began in 2016, and in 2017, the company obtained the necessary licenses to release six software packages for teaching science across six elementary school grades.

The primary mission of Ayandeh Amoozan Ata is to create a technological learning environment that facilitates scientific experimentation without spatial or material constraints, in a safe, multimedia-rich environment, enriched with Iranian cultural elements for students and future generations. This study evaluates the success or failure of the Ata Virtual Science Laboratory as an educational innovation, aiming to uncover new strengths and weaknesses.

Bakhshyarvand et al. (2022) conducted a study titled *"The Use of Virtual Laboratories in Increasing Academic Motivation and Improving Learning."* This study aimed to explore the use of virtual laboratories in enhancing students' academic motivation and learning outcomes. The research adopted a descriptive-documentary approach, utilizing a library-based method and a review of relevant theoretical sources. After defining key concepts and reviewing previous research, the study examined learning and its influencing factors, educational methods, virtual laboratories, their history and benefits, and academic motivation. The findings indicated that teachers use various methods, including conducting experiments, to engage students in learning. However, this is often not effectively implemented due to several obstacles, such as a lack of facilities, limited laboratory equipment, the perceived insignificance of conducting experiments among some teachers, administrators, and officials, the high costs of some experiments, and the potential dangers of certain experiments. Consequently, the use of virtual and simulated environments in education is crucial to compensate for the lack of laboratory resources and to conduct experiments in a safe and cost-effective manner.

Dohani et al. (2024) conducted a study titled *"The Effectiveness of a Web-Based Virtual Laboratory on the Self-Regulated Learning of Eighth-Grade Students."* Self-regulated learning (SRL) is a crucial factor in online education and is defined as the active management of one's learning process to achieve a desired outcome. However, many issues regarding how to improve cognitive and self-regulation strategies in online learning environments, where teachers are not physically present, remain unresolved. This study aimed to examine the effectiveness of a web-based virtual laboratory in enhancing students' SRL. A quasi-experimental pretest-posttest design with a control group was conducted, involving 40 female students aged 14 to 15. While students in the experimental group engaged in hands-on activities using the web-based virtual laboratory, students in the control group used a physical laboratory. The results showed that the virtual laboratory significantly improved students' metacognitive self-regulation, effort regulation, peer learning, and overall SRL compared to the physical laboratory. These findings can be attributed to the way students learn using virtual laboratories—for instance, they can explore the virtual laboratory website at their own pace, anytime and anywhere.

Noufal and Khalaf (2021) conducted a study in Jordan where Inam and Mohammed applied Rogers' Diffusion of Innovation Theory to evaluate a national curriculum innovation called the *"Health Schools Program."* According to these researchers, the Diffusion of Innovation Theory can help education scholars understand the reasons behind the implementation process, the extent, and the speed at which innovation spreads within an educational system.

Al-Mozaan et al. (2023) conducted a study titled *"Learning Analytics in Virtual Laboratories: A Systematic Literature Review of Experimental Research."* To date, no study has systematically combined research on virtual laboratories and learning analytics, which is the gap this study aimed to fill. A systematic review was conducted to synthesize empirical research on learning analytics in virtual laboratories. A total of 21 articles published between 2015 and 2021 were analyzed. The results showed that 48% of the studies were conducted in higher education, with a primary focus on the medical field. A wide range of virtual laboratory platforms exists, and most of the learning analytics used in the reviewed articles were derived from student log files tracking their actions. Learning analytics were utilized to measure students' performance, activities, perceptions, and behaviors in virtual laboratories. These studies covered a broad spectrum of research areas, platforms, and analytical approaches. However, the landscape of platforms and applications remains fragmented, small-scale, and exploratory, with learning analytics not yet fully leveraged to support learning and instruction. Therefore, educators may need to develop shared standards, protocols, or platforms to build upon each other's findings and enhance collective knowledge.

Dyberg et al. (2017) investigated the potential benefits of virtual simulations and laboratory exercises in science education. This study reported the findings of a pilot study on students' attitudes, motivation, and self-efficacy when using a virtual laboratory program. The results indicated that after using virtual laboratories, students felt significantly more confident and comfortable working with laboratory equipment. Teachers also observed that students engaged in higher-level discussions compared to previous years when the program was not used.

Diah Puji Lestari et al. (2023) conducted a study titled *"The Impact of Integrating Virtual Science Laboratories with Demonstration Methods on High School Students' Scientific Literacy."* A virtual laboratory is computer software capable of mathematically modeling laboratory equipment in a simulation format. A virtual laboratory does not replace a real laboratory but is used to complement and enhance its weaknesses. This study aimed to determine the impact of integrating virtual laboratories with demonstration methods on high school students' scientific literacy. The research followed a quasi-experimental design, with a sample of 102 students (aged 12–14) from a secondary school in Yogyakarta, Indonesia, divided into three groups: Experimental Group 1, Experimental Group 2, and a Control Group. All three groups underwent pretests and posttests. Experimental Group 1 used a combination of virtual laboratories with demonstration methods, Experimental Group 2 used only virtual laboratories, and the Control Group used only demonstration methods. Scientific literacy skills were measured using multiple-choice tests before and after the intervention. Statistical tests, including ANOVA, were used to determine the effectiveness of integrating virtual laboratories with demonstration methods in enhancing scientific literacy. The within-subject effects test revealed significant differences in pretest-posttest scores for scientific literacy ($F = 10.50$; $p < 0.05$) across the groups. Pairwise comparisons indicated significant improvements in pretest-posttest scientific literacy scores in all groups ($p < 0.05$). The effect size results (partial eta squared) showed that Experimental Group 1 achieved an 84.5% improvement in scientific literacy, Experimental Group 2 achieved 78.5%, and the Control Group achieved 74.3%. Therefore, it can be concluded that Experimental Group 1 (the combination of virtual laboratories with demonstration methods) contributed most effectively to improving scientific literacy compared to the other groups.

Lucas and Ivana (2020) used evaluative aspects of Rogers' Diffusion of Innovation Theory to analyze the perspectives of elementary school teachers in Prague, Czech Republic, on digital literacy innovation.

Santos (2021) conducted a meta-analysis at the College of Science Education at De La Salle University, Philippines, titled *"Meta-Analysis: The Effects of Virtual Laboratories on Science Education."* The study yielded significant findings. One key result indicated that elementary and secondary school students benefited more from virtual laboratories compared to undergraduate students. Another finding compared the effects of virtual laboratories on different science subjects, including chemistry, physics, biology, and earth sciences. The results showed that chemistry had the most positive impact from the use of virtual laboratories.

Virtual Laboratory

A virtual laboratory is an interactive and simulated space that allows users to conduct experiments and scientific activities virtually. These environments are typically created using computers and the internet, enabling users to interact with virtual equipment and materials, collect data, and analyze results. As an innovation, virtual laboratories promote a flexible, inclusive, and sustainable approach to complement knowledge and educational resources, eliminating common limitations in teaching laboratory skills (Achuthan et al., 2020). Virtual laboratories are simulated environments that replicate real-world laboratory activities, allowing students to engage in hands-on learning experiences without time, location, or physical resource constraints (Raini & Aldila, 2023).

Educational Evaluation

Educational evaluation is a systematic and structured process aimed at collecting, analyzing, and interpreting information about students' learning, the effectiveness of teaching methods, curricula, and the overall educational system. The primary goal of educational evaluation is to improve the quality of teaching and learning (Hassan et al., 2022).

Innovation

Innovation refers to the realization of creativity, meaning the operationalization and implementation of new ideas. From this perspective, innovation can be considered the tangible execution of mental creativity. An organization that encourages innovation is one that promotes unconventional perspectives on problems or unique solutions, embraces risk, is knowledge-based, possesses a developed culture and human resources, and maintains a flexible organizational structure (Fattahi & Ghasemi, 2015). In general, innovation involves the creation and introduction of new ideas, products, processes, or services that add value, leading to positive changes and continuous improvements in various aspects of human life (Rodriguez, 2010).

Everett Rogers Diffusion of Innovation Theory

The Diffusion of Innovation Theory, proposed by Everett Rogers, examines how new ideas, products, or services spread and are adopted within a society. This theory helps us understand why some innovations are quickly embraced while others face resistance. Additionally, it is used to assess the success of innovations within specific theoretical frameworks (Hosseinikha, 2008).

3. Method

This study follows a quantitative approach and is classified as an applied research in terms of its objective, while methodologically, it is descriptive and of the survey type. The target population consists of elementary school teachers in Iran who have had firsthand, practical experience using the Ata Virtual Science Laboratory. The sample population includes elementary school teachers from the four districts of Karaj and the Kaghazkonan region in East Azerbaijan province. Based on Krejcie and Morgan's sample size table, the sample size was determined to be 70 teachers. This study employed a non-probability, convenience sampling method. A standardized questionnaire was used as the data collection instrument, designed based on the five criteria of Everett Rogers' Diffusion of Innovations Model, comprising 25 questions. The data collected through the questionnaires were analyzed using descriptive and inferential statistical techniques with SPSS 22 software.

Ultimately, the obtained results were meticulously analyzed and examined. This research methodology enables a comprehensive and precise assessment of the alignment between the Ata Virtual Science Laboratory and the five key criteria of Rogers' Theory, determining whether the laboratory is considered successful overall. The reliability of the questionnaire was assessed through a pilot study using statistical techniques, specifically Cronbach's alpha, with the aid of SPSS software. The calculated Cronbach's alpha coefficient was 0.901, indicating a high level of internal consistency among the questionnaire items. The results confirm that the questionnaire items exhibit an acceptable degree of internal correlation.

To conduct the data collection process, necessary coordination was made with school administrators and educational experts from the studied regions. Subsequently, elementary school teachers who had firsthand, practical experience using the Ata Virtual Science Laboratory were selected. Additionally, in certain cases, the Ata Virtual Science Laboratory software was provided to teachers of various grade levels, enabling them to practically integrate the software into their teaching and classroom activities. This approach ensured that participants gained sufficient familiarity and experience to effectively engage in the study and complete the questionnaire.

4. Finding

Main Research Question: *To what extent does the Ata Virtual Science Laboratory align with the five key criteria of Rogers' Diffusion of Innovations Theory from the perspective of elementary school teachers?*

Table 1. *Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with Rogers' Five Criteria*

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0/001	69	33.617	55	5.99	79.10	

The data presented in Table 1 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the five criteria of Rogers' Theory is significantly above average (79.10 > 55). This finding suggests that elementary school teachers perceive the laboratory as possessing innovative characteristics, including relative advantage, compatibility, simplicity, trialability, and observability, at a level above the expected average. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

To further examine the alignment of the Ata Virtual Science Laboratory with each of Rogers' five characteristics, the following section presents a detailed analysis based on the research sub-questions, with results summarized in the tables below.

Sub-Question 1: *To what extent does the Ata Virtual Science Laboratory exhibit relative advantage from the perspective of elementary school teachers?*

Table 2. *Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with the "Relative Advantage" Criterion*

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0/001	69	13.772	11	2.84	15.68	

The data presented in Table 2 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the relative advantage criterion is significantly above average (15.68 > 11). This result suggests that elementary school teachers perceive the laboratory as providing a greater relative advantage compared to traditional methods. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

Sub-Question 2: *To what extent does the Ata Virtual Science Laboratory demonstrate compatibility from the perspective of elementary school teachers?*

Table 3. *Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with the "Compatibility" Criterion*

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0.001	69	15.950	11	2.54	15.64	

The data presented in Table 3 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the compatibility criterion is significantly above average (15.64 > 11). This result suggests that elementary school teachers perceive the laboratory as highly compatible with existing values, past experiences, and the needs of adopters. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

Sub-Question 3: *To what extent is the Ata Virtual Science Laboratory characterized by ease of use and comprehensibility from the perspective of elementary school teachers?*

Table 4. *Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with the "Simplicity" Criterion*

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0.001	69	19.897	11	1.88	15.48	

The data presented in Table 4 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the simplicity criterion is significantly above average (15.48 > 11). This result suggests that elementary school teachers perceive the laboratory as easy to use and understandable. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

Sub-Question 4: *To what extent does the Ata Virtual Science Laboratory meet the criterion of trialability from the perspective of elementary school teachers?*

Table 5. *Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with the "Trialability" Criterion*

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0.001	69	10.509	11	1.32	14.80	

The data presented in Table 5 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the trialability criterion is significantly above average (14.80 > 11). This result suggests that elementary school teachers perceive the laboratory as having a high degree of trialability, meaning that they find it feasible to experiment with the software before making a full commitment to its adoption. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

Sub-Question 5: *To what extent does the Ata Virtual Science Laboratory fulfill the criterion of observability from the perspective of elementary school teachers?*

Table 6. Elementary School Teachers' Perceptions of the Alignment of the Ata Virtual Science Laboratory with the "Observability" Criterion

Independent t-test			Hypothetical Mean	Mean Score		Rogers' Five Criteria
p	df	t		Standard Deviation	Mean	
0.001	69	19.249	11	2.43	16.60	

The data presented in Table 6 indicate that the mean score of teachers' responses regarding the alignment of the Ata Virtual Science Laboratory with the observability criterion is significantly above average (16.60 > 11). This result suggests that elementary school teachers perceive the laboratory as highly observable, meaning that the results and benefits of using the virtual laboratory are clearly visible and demonstrable in educational settings. Furthermore, since the significance level (p-value) is less than 0.05, this result is statistically significant and confirmed.

5. Conclusion

Main Question: To what extent does the ATA Virtual Science Laboratory align with the five criteria of Rogers' Diffusion of Innovations theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the five characteristics of Rogers' theory was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success was above average and statistically significant. This finding means that teachers’ acceptance or decision to use the ATA Virtual Science Laboratory as a new technology was assessed as satisfactory and relatively high, based on their perceptions of this technology’s attributes, such as relative advantage, compatibility, complexity, trialability, and observability. The descriptive findings of this study showed that more than half of the teachers (61%) believed that the ATA Virtual Science Laboratory possessed the five characteristics of Rogers' theory and was, therefore, evaluated as successful.

This level of satisfaction with the performance of the virtual laboratory has been observed in previous research. For instance, Joifel et al. (2013) concluded that applying Rogers' Diffusion of Innovations theory to explain teachers' acceptance of interactive whiteboards in modern Jordanian schools led to the transformation of traditional teaching methods into more modern and interactive approaches. Nuan and Pamheiren (2019) found that virtual laboratories positively impact students' learning outcomes and that Rogers' theory provides a useful framework for understanding the diffusion and adoption of technology. Mousavi and Afsari Sardari (2019) concluded that smartboards positively affect learning, retention, and enthusiasm for learning. Mahmoudi and Qureshi (2023) found that using smartboards by teachers enables students to grasp academic concepts more effectively and leaves a more lasting impact on their minds. Software and simulators change students' perceptions of difficult and incomprehensible subjects, making learning easier for them.

Mehdi Zadeh et al. (2011) studied the impact of virtual laboratories on high school students' chemistry learning and confirmed that a simulated environment enhances students' chemistry learning. They also found that gender and the type of laboratory influenced students' engagement in learning chemistry. In another study, Mansouri et al. (2011) examined the attitudes of students at Payame Noor University in Gonbad Kavous toward virtual laboratories and found a general consensus in favor of virtual laboratories, with no negative attitudes among students.

The successful evaluation of the ATA Virtual Science Laboratory in terms of Rogers' five criteria suggests that the laboratory's ability to simulate an experimental environment for users (students) and allow experiments to be conducted without spatial or temporal limitations has contributed to its acceptance and adoption by teachers and users.

According to the Diffusion of Innovations theory, an innovation does not necessarily have to be a completely new idea; rather, it should appear novel to those who adopt it. In other words, innovation does not mean rejecting everything old and embracing everything modern but rather integrating both old and new elements into a dynamic and creative combination. For example, replacing rectangular white chalk with cylindrical and colored chalk is a type of innovation that does not have much objective novelty but appears new from the perspective of teachers and students.

Therefore, based on Rogers' theory, the criterion for the success of an innovation or educational innovation activities is the level of acceptance or perception of its users. While the ATA Virtual Science Laboratory has been evaluated as successful by the teachers in this study, it is important to note that if the necessary infrastructure for implementing innovative methods in virtual laboratories is not provided, the technology may not be accepted by its users. For example, Salarvandian et al. (2015) found that the adoption of smartboards as an educational innovation was not well received, and the diffusion rate was not considered successful due to challenges such as insufficient support for innovation, fear of innovation, and other obstacles in implementation.

As mentioned earlier, Rogers' theory includes five characteristics: relative advantage, compatibility, simplicity, trialability, and observability, all of which have been examined in this study, with results explained in response to the research sub-questions.

Sub-question (1): To what extent does the ATA Virtual Science Laboratory align with the "Relative Advantage" criterion in Rogers' theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the relative advantage characteristic was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success regarding relative advantage was above average and statistically significant. This means that the relative advantage of the ATA Virtual Science Laboratory has led to teachers' increased willingness to adopt it as a new technology. The descriptive findings showed that more than half of the teachers (69%) believed that the ATA Virtual Science Laboratory possessed the characteristic of relative advantage.

It appears that the main reason for the positive reception of the ATA Virtual Science Laboratory in terms of relative advantage is its ease of use. The descriptive results of this study support this argument. Approximately 66% of teachers stated that the ATA Virtual Science Laboratory is more useful and applicable. About 63% noted that it has fewer disadvantages. Around 72% mentioned that it requires less time. About 63% stated that it requires less effort. And 34% indicated that it requires fewer resources. Among these factors, the most significant advantage of the ATA Virtual Science Laboratory is the time-saving aspect, which allows experiments to be conducted quickly and accurately. However, despite its relative advantage, the lowest acceptance rate was related to the need for fewer resources, indicating that this aspect requires further attention. Overall, factors such as usefulness, fewer disadvantages, time efficiency, reduced effort, and lower resource requirements contribute to the diffusion and adoption of the ATA Virtual Science Laboratory and other educational innovations.

Sub-question (2): To what extent does the ATA Virtual Science Laboratory align with the "Compatibility" criterion in Rogers' theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the compatibility characteristic was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success regarding compatibility was above average and statistically significant. This means that the compatibility of the ATA Virtual Science Laboratory has led to teachers’ increased willingness to adopt it as a new technology. The descriptive findings showed that more than half of the teachers (51%) believed that the ATA Virtual Science Laboratory possessed the characteristic of compatibility.

The main reason for the positive reception of the ATA Virtual Science Laboratory in terms of compatibility appears to be its alignment with commonly held values, past experiences, and the needs of potential users. The descriptive results of this study support this argument. Approximately 53% of teachers stated that the ATA Virtual Science Laboratory aligns with teachers’ and students’ values and criteria. About 69% mentioned that it is compatible with teachers' and students’ needs. Around 57% stated that it aligns with the interests and real experiences of teachers and students. About 32% noted that it is compatible with school policies and conditions. And 53% indicated that it aligns with parents' expectations and needs. The highest compatibility rate was related to alignment with teachers' and students’ needs, suggesting that the virtual laboratory offers engaging and diverse activities tailored to different age groups. Overall, factors such as compatibility with values, needs, real experiences, school policies, and parental expectations contribute to the diffusion and adoption of the ATA Virtual Science Laboratory and other educational innovations.

Sub-question (3): To what extent does the ATA Virtual Science Laboratory align with the "Simplicity" criterion in Rogers' theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the simplicity characteristic was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success regarding simplicity was above average and statistically significant. This means that the simplicity of the ATA Virtual Science Laboratory has led to teachers' increased willingness to adopt it as a new technology. The descriptive findings showed that more than half of the teachers (50%) believed that the ATA Virtual Science Laboratory possessed the characteristic of simplicity.

The main reason for the positive reception of the ATA Virtual Science Laboratory in terms of simplicity appears to be teachers' perception that it is easy to understand and use. The descriptive results of this study support this argument. Approximately 62% of teachers stated that the laboratory has low complexity. About 55% mentioned that it has an easy operational process. Around 69% stated that it requires fewer materials and resources. About 60% noted that it involves fewer unnecessary steps. The highest simplicity rating was related to the reduced need for materials and resources, suggesting that the laboratory provides a more accessible and efficient learning experience. Overall, factors such as low complexity, ease of use, minimal resource requirements, and streamlined processes contribute to the diffusion and adoption of the ATA Virtual Science Laboratory and other educational innovations.

Sub-question (4): To what extent does the ATA Virtual Science Laboratory align with the "Trialability" criterion in Rogers' theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the trialability characteristic was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success regarding trialability was above average and statistically significant. This means that the trialability of the ATA Virtual Science Laboratory has led to teachers' increased willingness to adopt it as a new technology. The descriptive findings showed that more than half of the teachers (63%) believed that the ATA Virtual Science Laboratory possessed the characteristic of trialability.

The main reason for the positive reception of the ATA Virtual Science Laboratory in terms of trialability appears to be its ability to allow experimentation and repeated testing. The descriptive results of this study support this argument. Approximately 64% of teachers stated that the laboratory is highly accessible. About 52% mentioned that it does not require physical materials. Around 77% stated that it enables the repetition of experiments multiple times. About 65% noted that it is compatible with all operating systems and offers extensive support services. Additionally, 75% indicated that the ATA Virtual Science Laboratory has no spatial or temporal limitations, allowing teachers and students to use it both in and outside the classroom. The highest trialability rating was related to the ability to repeat experiments multiple times, suggesting that the laboratory provides a flexible and risk-free environment for scientific exploration. Overall, factors such as high accessibility, no need for physical materials, repeatability of experiments, compatibility with various systems, extensive support services, and flexibility in terms of time and location contribute to the diffusion and adoption of the ATA Virtual Science Laboratory and other educational innovations.

Sub-question (5): To what extent does the ATA Virtual Science Laboratory align with the "Observability" criterion in Rogers' theory?

Findings indicated that the alignment of the ATA Virtual Science Laboratory with the observability characteristic was evaluated as successful. According to teachers with experience using the ATA Virtual Science Laboratory, the level of alignment or success regarding observability was above average and statistically significant. This means that the observability of the ATA Virtual Science Laboratory has led to teachers' increased willingness to adopt it as a new technology. The descriptive findings showed that more than half of the teachers (58%) believed that the ATA Virtual Science Laboratory possessed the characteristic of observability.

The primary reason for the positive reception of the ATA Virtual Science Laboratory in terms of observability appears to be its ability to make the outcomes of experiments tangible and visible. The descriptive results of this study support this argument. Approximately 40% of teachers stated that appropriate training workshops had been provided to ensure correct usage of the laboratory. About 53% mentioned that the ATA Virtual Science Laboratory produces clear and tangible results for others. Around 66% stated that the use of the virtual laboratory, through educational videos, hands-on experiments conducted in real environments, concept maps, interactive assessments, and multimedia features, has led to deeper learning and long-term retention of scientific concepts among students. About 61% noted that the ATA Virtual Science Laboratory is designed and implemented within a fully multimedia-based environment, aligned with the officially approved school curricula and their latest updates.

Based on these results, it can be concluded that factors such as training workshops, proper awareness and guidance for optimal use, tangible and observable experimental outcomes, various educational opportunities (including videos, real-world experiments, concept maps, engaging assessments, and multimedia environments), and alignment with school curricula play a crucial role in enhancing the perception, diffusion, and adoption of the ATA Virtual Science Laboratory and other educational innovations.

Overall, the findings indicated that, from the teachers' perspective, the ATA Virtual Science Laboratory aligns with all five characteristics of Rogers' theory. The success level of each component was above average and statistically significant. More than 61% of teachers stated that the ATA Virtual Science Laboratory was compatible with Rogers' five characteristics. In conclusion, the ATA Virtual Science Laboratory was perceived to exhibit relative advantage, compatibility, simplicity, trialability, and observability, making it a valuable innovation in educational settings.

Funding: Taiwan's Ministry of Education supported this work under Grant PED1110303.
Conflict of interest: The report does not recognize any conflicts of interest.

References

Abdulwahed, M., & 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

Achuthan, K., Nedungadi, P., Kolil, V., Diwakar, S., & Raman, R. (2020). Innovation adoption and diffusion of virtual laboratories. https://doi.org/10.3991/ijoe.v16i09.11685

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 and Technology Education*, *20*(3), em2410. https://doi.org/10.29333/ejmste/14282

Bakhshyarvand, S., Birami Nia, B., Parvin, S., & Vatankhah, F. (2022). *Using virtual laboratories to increase academic motivation and improve learning*. 17th National Conference on Psychology, Social Sciences, and Education. [in Persian]

Cirus, L., & Simonova, I. (2020, August). Rogers' diffusion of innovation theory applied on primary education: Case study of Czech teachers. In *2020 International Symposium on Educational Technology (ISET)* (pp. 33-37). IEEE. https://doi.org/10.1109/ISET49818.2020.00017

Cirus, L., & Simonova, I. (2021). Pupils' digital literacy reflected in teachers' attitudes towards ICT: Case study of the Czech Republic. *SN Computer Science*, 2(3), 231. https://doi.org/10.1007/s42979-021-00567-y

Lestari, D. P., Supahar, Paidi, Suwarjo, & Herianto. (2023). Effect of science virtual laboratory combination with demonstration methods on lower-secondary school students' scientific literacy ability in a science course. *Education and Information Technologies*, *28*(12), 16153-16175. https://doi.org/10.1007/s10639-023-11857-8

Durkaya, F. (2023). Virtual laboratory use in science education with digitalization. *Hungarian Educational Research Journal*, 13(2), 189–211. https://doi.org/10.1556/063.2022.00141

Dyrberg, N. R., Treusch, A. H., & Wiegand, C. (2017). Virtual laboratories in science education: Students' motivation and experiences in two tertiary biology courses. *Journal of Biological Education*, 51(4), 358–374. https://doi.org/10.1080/00219266.2016.1257498

Elmoazen, R., Saqr, M., Khalil, M., & Wasson, B. (2023). Learning analytics in virtual laboratories: A systematic literature review of empirical research. *Smart Learning Environments*. https://doi.org/10.1186/s40561-023-00244-y

Fattahi, M., & Sadeghi, Q. (2015). The impact of innovation and creativity on relationship marketing and organizational performance. *International Conference on Research in Science and Technology*. [in Persian]

Hosseinkhah, A. (2008). A review of the diffusion of innovation theory in the field of education. *Journal of Educational Innovations*, 26(7), 151-178. [in Persian]

Luliyarti, D. S., & Prasetyo, Z. K. (2021). *Development of inquiry-based multimedia learning module with PhET simulation in Newton's law of motion*. 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS). https://doi.org/10.2991/assehr.k.210305.071

Nofal, B. M., & Khalaf, I. (2021). Using Roger's diffusion of innovation theory to implement the healthy schools' national accreditation. *Medico-Legal Update*, 21(3), 171–176. https://doi.org/10.37506/mlu.v21i3.2980

Rini, E. F. S., & Aldila, F. T. (2023). Practicum activity: Analysis of science process skills and students' critical thinking skills. *Integrated Science Education Journal*, 4(2), 54–61. https://doi.org/10.37251/isej.v4i2.322

Saddadi, M. (2019). The necessity of reform in science education in Iran. *Research in Chemistry Education*, 1(3), 1–4. [in Persian]

Salehi, K., Ghazemi, M., Fallahi, V., & Namdari, V. (2016). *Cognitive thematic analysis of the lived experiences of professors regarding the quality of virtual education programs*. Applied Psychological Research Journal (Psychology and Educational Sciences). [in Persian]

Santos, M. L., & Prudente, M. (2021). Effectiveness of virtual laboratories in science education: A meta-analysis. *International Journal of Information and Education Technology*, 11, 12.

Sapriati, A., Jayanti Suhandoko, A., Yundayani, A., Karim, A., Kusmawan, U., Adnan, H. M., & Azhary Suhandoko, A. (2023). The effect of virtual laboratories on improving students' SRL: An umbrella systematic review. *Education Sciences*, 13(3). https://doi.org/10.3390/educsci13030222

Sever, S., Yurumezoglu, K., & Oguz-Unver, A. (2010). Comparison teaching strategies of videotaped and demonstration experiments in inquiry-based science education. *Procedia-Social and Behavioral Sciences*, *2*(2), 5619-5624. https://doi.org/10.1016/j.sbspro.2010.03.916

Vasiliadou, R. (2020). Virtual laboratories during coronavirus (COVID-19) pandemic. Biochemistry and Molecular Biology Education, 48(5), 482–483. https://doi.org/10.1002/bmb.21407

Wang, C., Ma, Y., & Wu, F. (2020). Comparative learning performance and mental involvement in collaborative inquiry learning: three modalities of using virtual lever manipulative. *Journal of Science Education and Technology*, *29*(5), 587-596. https://doi.org/10.1007/s10956-020-09838-4

Wilson, J. (2001). Educational innovation for development. Bangkok: UNESCO Principal Regional Office for Asia and the Pacific.