cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

Development and Validation of a Computer Simulation-Based Laboratory Manual for Gas Laws

Leomel Amparado[1]; Rachel Tapia[2]; Joje Mar Sanchez[3]

Graduate School Department, College of Teacher Education of Cebu Normal University, Cebu City, Philippines
[1] main.202268@cnu.edu.ph; [2] main.23001901@cnu.edu.ph; [3] sanchezj@cnu.edu.ph

DOI: 10.47760/cognizance.2025.v05i01.026

Abstract: This study developed and validated a laboratory manual for teaching gas laws using computer-aided simulations to address challenges in chemistry education. Utilizing a descriptive educational and research model alongside the ADDIE framework, the manual was evaluated by expert validators and tested with Grade 11 STEM students and teachers. The validation results by the experts were evident in all criteria, including pedagogical approach, content relevance, technology integration, assessment strategies, and teacher support and professional development. The manual effectively promotes student-centered learning, aligns with curriculum standards, and enhances engagement and comprehension through technology integration, providing a valuable resource for teachers and improving student outcomes.

Keywords: Computer simulations, gas laws, laboratory manual, chemistry education, science education

I. Introduction

Babalola (2013) defined chemistry education as a field of study focusing on teaching and learning chemistry content. It involves research, theory, and practices related to teaching chemistry. The core objective is to cultivate a scientific way of thinking in students and equip them to grasp complex and abstract chemical concepts. Chemistry education's success hinges on its ability to meet the needs of individuals, society, and the nation's development. Therefore, education systems must embrace evolving educational standards (Hagverdiyev et al., 2021).

However, effectively teaching these abstract concepts presents a unique challenge for educators. The intricate world of invisible atoms and complex reactions necessitates effective instructional strategies and materials to bridge the gap between abstract ideas and student comprehension (Lee & Abdullah, 2011). These tools, encompassing simulations, models, and engaging activities, cater to diverse visual, auditory, or kinesthetic learning styles.

Beyond rote memorization, problem-solving and inquiry-based learning foster a deeper understanding of chemical principles (Lee & Abdullah, 2011). Furthermore, incorporating real-world applications and interactive elements enhances student motivation and fosters curiosity about the subject (Prince & Felder, 2006). The benefits extend far beyond content mastery. Collaborative activities and laboratories nurture essential skills such as communication, critical thinking, and analysis. These skills are invaluable in the chemistry classroom and throughout a student's academic and professional career. In essence, strategically designed instructional materials and engaging activities are the cornerstone for a dynamic and successful chemistry learning experience.

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

Unfortunately, chemistry education in the Philippines faces several challenges, as evidenced by various studies. Mecampong (2017) highlights a lack of adequate preparation among science teachers to teach chemistry effectively under the K-12 curriculum. This results in issues with content delivery, pedagogy, and assessment. Furthermore, the Philippines' performance in science education, as measured by PISA 2018 (Orbe et al., 2018), falls short compared to other participating nations. This prompted the Department of Education to propose programs to improve academic performance and overall educational quality.

Looking beyond K-12, Bonito (2022) identifies several factors affecting students' success in chemistry learning at the university level. These include classroom dynamics, learning environment, study habits, chosen academic track, and teacher quality. The recent shift to online learning during the COVID-19 pandemic further emphasized the need for technology-enhanced teaching practices among university chemistry teachers, particularly in a country with limited experience in online pedagogies (Mangubat, 2023). Addressing these challenges is crucial to improving the country's overall state of chemistry education.

In this context, integrating technology in education, mainly through Computer-Based Simulations (CBS), presents a compelling solution to the challenges faced by chemistry education. According to Meccawy (2017), CBS can visually and interactively demonstrate intricate processes, such as electrolysis, that are otherwise difficult to grasp through traditional teaching methods. This technology uses animated color and graphic images to present dynamic and complex concepts, making them more accessible and comprehensible for students. Shamai (2001) stated that CBS allows students to visualize physical phenomena in a three-dimensional form, enhancing their cognitive understanding and retention of the material. Additionally, the use of CBS can reduce reliance on costly physical experiments, as Allesi and Trollip (1991) noted, thereby making the learning process more efficient and economical. Furthermore, Wesi (2011) pointed out that CBS helps address the limitations of conventional instruction that often leads to rote memorization rather than meaningful learning. By creating a more engaging and interactive learning environment, CBS can positively influence students' attitudes, cognitive development, and academic achievements in chemistry.

This study aimed to develop and validate a laboratory manual for gas laws using computer-aided simulations. Specifically, it aims to develop a laboratory manual for gas laws using computer-aided simulations and determine the validity of the laboratory manual in terms of (1) pedagogical approach, (2) content relevance, (3) technology integration, and (4) assessment strategies and (5) teacher support and professional development.

By investigating the effectiveness of computer simulations in teaching gas laws, the study contributes to ongoing efforts to enhance the teaching and learning of complex scientific concepts. This could potentially transform chemistry education into a more interactive, accessible, and effective experience for both students and educators.

II. METHODOLOGY

Design

This study employed a descriptive-educational research and development (R&D) model to create a laboratory manual focused on gas laws using computer simulations. According to Borg and Gall, as cited in Tolentino et al. (2020), educational R&D is a research approach employed to develop, produce, and evaluate instructional materials and intervention programs through rigorous research. This model was particularly suitable for this study, as we aimed to address the challenges senior high school students faced in grasping gas law concepts, which were identified through a needs assessment analysis.

Environment

The research occurred at Cebu Normal University and a private high school in Danao City.

Participants

The study involved two distinct groups of participants. The first group comprised 18 expert validators, all current Master of Arts in Education students majoring in Science Education at Cebu Normal University. These expert validators assessed the laboratory manual using the following criteria: (1) pedagogical approach, (2) content relevance, (3) technology integration, (4) assessment strategies, and (5) teacher support and professional development.

The second group consisted of 10 Grade 11 STEM students and five science teachers from a private school in Danao City. These participants were randomly selected to provide feedback on the innovation, addressing teacher and student perspectives.

Instruments

Expert validator's instrument

The expert validator's instrument was a validated tool for assessing instructional materials, adapted from the College of Teacher Education at Cebu Normal University. It evaluated the materials across five key areas: (1) pedagogical approach, (2) content relevance, (3) technology integration, (4) assessment strategies, and (5) teacher support and professional development. Each area included five indicators designed to comprehensively evaluate the effectiveness and quality of innovative teaching strategies, ensuring alignment with academic standards and a significant enhancement of student learning experiences.

Researcher-Made Questions

Researchers developed questions to gather comprehensive feedback on the innovation from students and teachers. These questions were specifically tailored to allow participants to provide detailed insights and constructive feedback on the manual.

Data Gathering

The development and validation of the laboratory manual for gas laws using computer-aided simulations followed the ADDIE model. The ADDIE model, which stands for Analysis, Design, Development, Implementation, and Evaluation, is a well-established instructional design framework. Although typically depicted linearly, the model's phases can be revisited to refine educational materials. (Instructional Design, 2015)

In the analysis phase, a comprehensive needs assessment was conducted to inform the development of the laboratory manual. This involved surveying students and teachers about their understanding of gas laws, identifying common problems, and gathering their thoughts on the topic. This feedback helped identify key focus areas for the manual's content and instructional strategies.

During the design phase, the structure and core components of the simulation activities in the laboratory manual were determined. The manual was designed to include clear and specific learning objectives, a list of required materials, step-by-step procedures for conducting simulations, and thought-provoking questions to encourage critical thinking and reinforce understanding. These elements were selected to ensure a comprehensive and engaging learning experience, leveraging computer-aided simulations to enhance understanding of gas laws.

The laboratory manual was written and compiled in the development phase. Its content was crafted to align with the identified learning objectives and effectively incorporate computer-aided simulations. The activities were designed to be student - centered and reflective, promoting active learning and a more profound comprehension of gas laws.

The implementation phase involved subjecting the manual to expert validation before its use in educational settings. The validation panel consisted of 18 expert validators, all current Master of Arts in Education students majoring in Science Education at Cebu Normal University. These experts evaluated the manual based on the pedagogical approach, content relevance, technology integration, assessment strategies, teacher support, and professional development. Additionally, feedback was gathered from 10 Grade 11 STEM students and five science teachers from a private school in Danao City. They were randomly selected to provide insights into the manual's usability and effectiveness, offering a practical perspective on its application in a classroom setting.

Finally, in the evaluation phase, feedback from both the expert validators and the surveyed students and teachers was collected and analyzed. Verbal suggestions and comments were considered for revising the

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

laboratory manual. After incorporating the feedback, the revised manual was evaluated to ensure its adequacy, coherence, appropriateness, and effectiveness in teaching gas laws using computer-aided simulations.

Data Analysis

The mean and standard deviation were utilized to evaluate the validity of the laboratory manual in terms of its pedagogical approach, content relevance, technology integration, assessment strategies, teacher support, and professional development. Additionally, thematic analysis, as outlined by Braun and Clarke (2006), was employed to analyze and interpret feedback from both students and teachers.

Ethical Considerations

This research adhered to strict ethical principles to ensure the rights and well-being of participants. Informed consent was obtained, and participants were fully informed about the study's purpose and procedures. Confidentiality was maintained by anonymizing personal data. Furthermore, participants were treated fairly and respectfully, and the study design minimized risks while maximizing potential benefits. Consistent with these ethical considerations, the study prioritized participant welfare and upheld its integrity by providing feedback opportunities to address concerns.

III. RESULTS AND DISCUSSION

This study aimed to develop and validate a Computer Simulation-Based Laboratory Manual for Gas Laws.

Students and Teachers' Experiences

On students

The research findings indicate that students rated their understanding of gas laws as good. However, they found applying gas law concepts to real-world scenarios and remembering the different gas laws challenging. Confidence in solving gas law problems was reported as somewhat confident. Students studied gas laws by attending lectures and classes and watching online videos. Regarding support and resources, students felt they received adequate support, with responses ranging from 'yes, definitely' to 'somewhat.' Interest in additional resources or support was mixed, with some students expressing a desire for more resources while others felt they had enough. None of the students had previously used computer simulations to study gas laws. They identified several advantages of computer simulations over traditional methods, such as the ability to perform potentially dangerous or expensive virtual experiments, immediate feedback on experimental outcomes, and the facilitation of deeper exploration through multiple traits and variations. Students suggested integrating computer simulations with interactive tutorials or explanations could enhance the learning experience. Unanimously, students recommended using computer simulations for studying gas laws and believed that these simulations would increase their interest and engagement in learning about gas laws.

On teachers

Teachers find teaching gas laws challenging due to abstract concepts and mathematical applications. They emphasize the importance of conceptual understanding, often using real-world examples and hands-on experiments to make the material relatable and engaging. Visual aids, interactive activities, and computer simulations are highlighted as practical tools for reinforcing students' understanding. Cross-disciplinary teaching and historical context can also enhance learning. Despite resource and safety constraints, teachers agree that combining traditional methods with modern technology, such as virtual labs and simulations, significantly improves student comprehension and interest in gas laws.

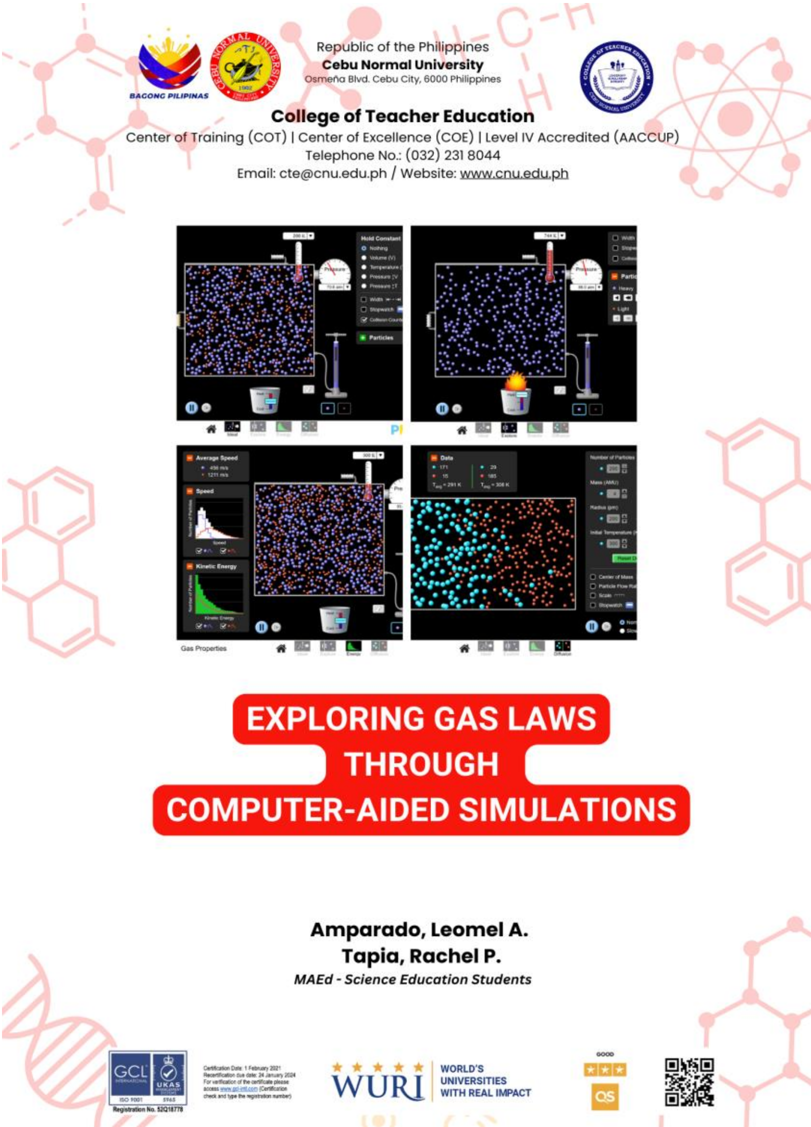
Toward the Innovation

Based on the needs analysis results from both students and teachers, this study developed a laboratory manual titled "Exploring Gas Laws through Computer-Aided Simulations." The simulations used were adopted from Colorado University's Physics Education Technology (PhET®) Project, specifically Interactive Simulations. The laboratory manual was designed using Microsoft Office 365 Publisher, a content layout and design software program.

The manual comprises several sections: the Cover Page, Preface, Table of Contents, Introduction, Understanding the Gas Laws, Simulation Activities, and References. It provides six simulation activities:

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

Exploring Boyle's Law: Pressure-Volume Relationship, Exploring Charles' Law: Temperature-Volume Relationship, Exploring Gay-Lussac's Law: Temperature-Pressure Relationship, Exploring Avogadro's Law: Moles-Pressure-Volume Relationship, Investigating the Combined Gas Law, and Investigating Effusion and Molecular Properties.



Experts' Validation of the Innovation

Pedagogical Approach

The data presented in Table 1 shows the experts' validation results for the pedagogical approach, which refers to the instructional methods and strategies employed by teachers to facilitate learning in the classroom. Experts rated the innovation as highly effective in encouraging student-centered learning (M = 4.12, SD = 1.27) and promoting inquiry-based learning in Science (M = 4.18, SD = 1.19), with both aspects being deemed evident. This emphasis on hands-on activities (M = 4.35, SD = 1.06) underscores the approach's practical and interactive nature. Furthermore, experts found the innovation to be very effective in facilitating critical thinking and problem-solving skills development (M = 4.24, SD = 0.90), indicating its potential to nurture higher-order thinking abilities among students.

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

However, while the innovation was acknowledged for supporting differentiated instruction to meet diverse student needs, this aspect received a relatively lower mean rating (M = 3.18, SD = 1.42), suggesting potential areas for improvement in tailoring instruction to individual student requirements. Nevertheless, the overall extent of the pedagogical approach was rated as evident (M = 4.01, SD = 1.23), indicating that the computer simulation-based manual provides a solid foundation for engaging students, promoting critical thinking, and fostering hands-on learning experiences in science education. Future research could explore ways to enhance differentiated instruction within this framework, ensuring all students have equitable learning opportunities.

Table 1.
Experts' validation results for a pedagogical approach

Indicator	Mean	SD	Description
The innovation encourages student-centered learning.	4.12	1.27	Evident
The innovation promotes inquiry-based learning in Science.	4.18	1.19	Evident
The innovation effectively integrates hands-on activities into Science instruction.	4.35	1.06	Very Evident
The innovation facilitates critical thinking and problem-solving skills development.	4.24	0.90	Very Evident
The innovation supports differentiated instruction to meet diverse student needs.	3.18	1.42	Evident
Overall Extent of Pedagogical Approach	*4.01*	*1.23*	*Evident*

Content Relevance

Table 2 reflected the experts' validation results for Content Relevance, demonstrating a strong alignment between the innovation and the content relevance indicators within the Science curriculum. Experts rated the innovation highly in alignment with the objectives of Science curriculum standards (M = 4.82, SD = 0.39), indicating a clear and cohesive integration of instructional goals with established educational standards. Furthermore, the incorporation of real-world applications of Science concepts was perceived as very evident (M = 4.29, SD = 0.99), underscoring the practical relevance of the innovation in connecting classroom learning with everyday experiences. However, while the innovation was recognized for addressing current scientific research and advancements (M = 4.18, SD = 1.13) and providing opportunities for project-based learning related to Science topics (M = 3.94, SD = 1.03), interdisciplinary connections with other subjects received a lower mean rating (M = 2.94, SD = 1.64), indicating a need for further integration of cross-disciplinary content. Nonetheless, the overall content relevance was rated as evident (M = 4.04, SD = 1.25), suggesting that the innovation effectively contextualizes Science education within relevant frameworks.

Table 2.
Experts' Validation Results for Content Relevance

Indicator	Mean	SD	Description
The innovation aligns with the objectives of Science curriculum standards.	4.82	0.39	Very Evident
The innovation incorporates real-world applications of Science concepts.	4.29	0.99	Very Evident
The innovation includes interdisciplinary connections with other subjects.	2.94	1.64	Moderately Evident
The innovation addresses current scientific research and advancements.	4.18	1.13	Evident
The innovation provides opportunities for students to engage in project-based learning related to Science topics.	3.94	1.03	Evident
Overall Extent of Content Relevance	*4.04*	*1.25*	*Evident*

Technology Integration

The data in Table 3 revealed the experts' validation results for technology integration. This domain incorporates technology tools and resources to enhance Science teaching and learning experiences. Experts rated the innovation highly in effectively integrating technology to support Science learning (M = 4.71, SD = 0.99), highlighting its seamless incorporation of digital tools to enrich instructional practices. Moreover, using digital tools for data collection and analysis received a very evident rating (M = 4.59, SD = 1.00), underscoring the innovation's capacity to facilitate empirical inquiry and scientific investigation. Additionally, the innovation was perceived as highly effective in promoting student collaboration and communication (M = 4.24, SD = 0.97), fostering a collaborative learning environment conducive to knowledge sharing and peer interaction. Furthermore, experts noted the innovation's success in promoting digital literacy skills development in Science (M = 4.41, SD = 1.00), indicating its role in equipping students with essential competencies for navigating the digital landscape. The leveraging of educational apps and simulations to reinforce Science concepts was also

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

very evident (M = 4.35, SD = 1.11), highlighting the diverse array of technological resources employed to deepen students' understanding of scientific principles. The overall extent of technology integration was rated as very evident (M = 4.46, SD = 1.01), demonstrating the laboratory manual's effectiveness in enhancing science education, specifically for understanding gas laws.

Table 3.
Experts' Validation Results for Technology Integration

Indicator	Mean	SD	Description
The innovation effectively integrates technology to enhance Science learning.	4.71	0.99	Very Evident
The innovation utilizes digital tools for data collection and analysis.	4.59	1.00	Very Evident
The innovation facilitates collaboration and communication among students.	4.24	0.97	Very Evident
TInnovation promotes the development of digital literacy skills in science.	4.41	1.00	Very Evident
The innovation leverages educational apps and simulations to reinforce Science concepts	4.35	1.11	Very Evident
Overall Extent of Technology Integration	*4.46*	*1.01*	*Very Evident*

Assessment Strategies

The data in Table 4 reveals the experts' validation results for assessment strategies, encompassing the methods and techniques used to evaluate student learning and progress in Science. While the innovation employed varied assessment methods (M = 3.41, SD = 1.33), indicating moderate evidence, there appears to be room for further diversification and refinement in the evaluation techniques utilized. Similarly, the inclusion of formative assessment practices to inform instructional decisions received a moderately evident rating (M = 3.59, SD = 1.50), suggesting opportunities for strengthening the integration of ongoing assessment processes to guide teaching and learning effectively. On a positive note, the innovation was perceived as very effective in providing opportunities for student self-assessment and reflection (M = 4.24, SD = 1.03), highlighting its capacity to empower learners in monitoring their progress and fostering metacognitive skills. Furthermore, experts noted the alignment of assessments with Science learning objectives and outcomes as evident (M = 4.18, SD = 1.07), indicating a cohesive linkage between assessment practices and instructional goals. Additionally, providing timely and constructive feedback to students to enhance their understanding of Science concepts was also rated as evident (M = 4.00, SD = 1.06), underscoring the innovation's commitment to facilitating continuous improvement and learning. Overall, the extent of assessment strategies within the innovation was perceived as evident (M = 3.88, SD = 1.23), suggesting a solid foundation for evaluating student learning in Science.

Table 4.
Experts' Validation Results for Assessment Strategies

Indicator	Mean	SD	Description
The innovation employs varied assessment methods to evaluate student learning in Science.	3.41	1.33	Moderately Evident
The innovation includes formative assessment practices to inform instructional decisions	3.59	1.50	Moderately Evident
The innovation provides opportunities for student self-assessment and reflection.	4.24	1.03	Very Evident
The innovation aligns assessments with Science learning objectives and outcomes.	4.18	1.07	Evident
The innovation offers students timely and constructive feedback to enhance their understanding of science.	4.00	1.06	Evident
Overall Extent of Assessment Strategies	*3.88*	*1.23*	*Evident*

Teacher Support and Professional Development

Table 5 shows the experts' validation results for Teacher Support and Professional Development, which involve initiatives and resources provided to educators to enhance their knowledge, skills, and confidence in delivering effective Science instruction. Experts rated the innovation favorably in providing adequate resources and materials to support Science teaching (M = 4.18, SD = 1.07), indicating a strong foundation for effective instructional delivery. Additionally, the innovation was perceived as offering extensive professional development opportunities to enhance teachers' Science pedagogy (M = 4.29, SD = 0.99), reflecting a commitment to continuous growth and improvement among educators. Furthermore, cultivating a supportive

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

school culture that values Science teaching innovations was deemed evident (M = 4.00, SD = 1.12), highlighting the importance of fostering an environment conducive to experimentation and exploration in educational practices. While collaboration and knowledge sharing among Science educators received a slightly lower mean rating (M = 3.88, SD = 1.32), there exists potential for strengthening collaborative efforts to facilitate collective learning and growth. Nevertheless, the innovation was recognized for acknowledging and celebrating teachers' contributions to improving Science instruction (M = 4.29, SD = 1.10), underscoring the significance of recognizing educators' dedication and commitment. Overall, the extent of teacher support and professional development within the innovation was rated as evident (M = 4.13, SD = 1.11).

Table 5.
Experts' Validation Results for Teacher Support and Professional Development

Indicator	Mean	SD	Description
The innovation provides adequate resources and materials to support Science teaching.	4.18	1.07	Evident
The innovation offers professional development opportunities to enhance teachers' Science pedagogy.	4.29	0.99	Very Evident
The innovation fosters a supportive school culture that values Science teaching innovations.	4.00	1.12	Evident
The innovation encourages collaboration and knowledge sharing among Science educators	3.88	1.32	Evident
The innovation recognizes and celebrates teachers' efforts in improving Science instruction.	4.29	1.10	Very Evident
Overall Extent of Teacher Support and Professional Development	*4.13*	*1.11*	*Evident*

Challenges of the innovation

The experts' validation results outlined some challenges that can be encountered by implementing a laboratory manual for gas laws using computer-aided simulations. One significant issue is the time students and teachers need to integrate and familiarize themselves with the new simulation tools. Many experts highlighted that this process could be excessively time-consuming, potentially disrupting already tight academic schedules.

Technological infrastructure poses another critical challenge. Digital tools, such as computers and smart devices, are not guaranteed in all educational settings, particularly in rural or underfunded areas of the country. Experts also pointed out that internet connectivity is essential for the functionality of simulations, like those from PhET Interactive Simulations, but unreliable internet access can lead to significant disruptions. Furthermore, technical issues, including software glitches and power outages, add complexity, making it difficult for schools without reliable infrastructure to maintain consistent and effective use of these simulations.

Socio-economic factors and teacher preparedness also impact the successful implementation of this innovation. Students from lower socio-economic backgrounds might lack access to personal computers or the internet at home, exacerbating educational disparities. Teacher preparedness is crucial, as some educators may not be adequately trained or comfortable using computer simulations, which can hinder practical guidance for students. Addressing these challenges involves improving digital infrastructure, providing targeted funding, ensuring reliable technical support, and offering professional development for teachers to facilitate the successful adoption and integration of this innovative educational tool.

Learning Opportunities of the Innovation

Using a laboratory manual for gas laws using computer-aided simulations offers numerous learning opportunities that can enhance students' understanding and engagement with the subject matter. One of the primary benefits is the ability for learners to explore the topic more deeply through interactive simulations provided by the laboratory manual. This hands-on approach allows students to visualize abstract concepts, such as the interactions between factors in gas laws, which are often challenging to grasp through traditional teaching methods alone. One expert noted, *"It can enhance students' learning since they can visually understand the concepts through the interactive simulations."*

Additionally, this innovation can significantly enhance students' mastery of the subject matter. Using simulations facilitates better visualization and conceptualization, leading to a more profound understanding of complex topics. According to experts, this method not only aids in understanding but also promotes digital

cognizancejournal.com
Leomel Amparado *et al*, Cognizance Journal of Multidisciplinary Studies, Vol.5, Issue.1, January 2025, pg. 305-315
(An Open Accessible, Multidisciplinary, Fully Refereed and Peer Reviewed Journal)
ISSN: 0976-7797
Impact Factor: 5.183
Index Copernicus Value (ICV) = 77.57

literacy, critical thinking, and engagement. For example, one expert mentioned that the innovation *"develops the student's critical thinking skills and boosts student's engagement inside the classroom."* Furthermore, the interactive nature of simulations can broaden students' understanding of gas laws and help them learn essential science process skills through observation and manipulation of virtual experiments.

Moreover, the innovation provides opportunities for individual and cooperative hands-on learning. This approach encourages students to communicate, collaborate, and think creatively and critically while manipulating technology. Experts highlighted that the simulations enable students to observe otherwise invisible phenomena, such as the behavior of gases, thereby making abstract concepts more tangible. For instance, one respondent stated, *"It can allow students to observe it visually, especially since gases are invisible."* Implementing computer-aided simulations in teaching gas laws can significantly enhance the learning experience by making abstract concepts accessible, engaging students in active learning, and developing essential skills for the digital age.

Impact of the innovation

Utilizing a laboratory manual for gas laws using computer-aided simulations is poised to impact the classroom environment significantly, primarily by enhancing students' mastery of the topic. This innovation facilitates a deeper understanding of gas laws by allowing students to visualize and manipulate abstract concepts through realistic virtual simulations. One expert noted, *"Students could learn in-depth from the lesson since they can visualize abstract concepts."* This hands-on, visual approach can improve learning performance and a better grasp complex scientific principle.

Moreover, the innovation contributes positively to teaching and learning by providing additional learning materials and fostering critical thinking. Experts highlighted that using simulations helps students navigate realistic scenarios, making learning more engaging and meaningful. For instance, one expert mentioned, *"It may improve the student's learning performance as they will try to navigate realistic scenarios using the virtual simulations."* Additionally, integrating technology into the classroom enhances students' interest and engagement, catering to varied learning styles and promoting a more interactive learning experience. This approach supports individual learning and encourages collaboration and active participation among students.

Furthermore, the innovation promotes a more authentic and meaningful educational experience than traditional methods. Engaging visual representations and manipulations strengthens student understanding and makes learning more enjoyable. Experts pointed out that this method allows for a macro-micro-symbolic presentation of lessons, enhancing the absorption and retention of information. One expert stated, *"It can greatly impact students as there will be a more meaningful experience than the usual practice of having students get bombarded with equations."* Implementing computer-aided simulations in teaching gas laws can transform the classroom dynamic, leading to more engaged, participative learners and a deeper, more comprehensive understanding of scientific concepts.

Areas of improvement for the innovation

While promising, the innovation of using a laboratory manual for gas laws with computer-aided simulations has several areas that could benefit from improvement to ensure it is more accessible and effective for a broader range of students. One critical improvement is to ensure that the innovation is accessible to all students, including those who do not have access to the necessary technology or stable internet connections. Experts emphasized the need for offline activities to accommodate schools without internet access. One expert suggested that it is important to *"include laboratory activities that incorporate offline activities so that schools with no internet can use the innovation."* This would help bridge the digital divide and ensure equal learning opportunities for all students.

Another area for improvement is providing alternatives and support in times of technical difficulties. This includes ensuring that the learning experience is not compromised due to technical issues such as power outages or software glitches. One expert recommended "*providing alternatives in times of technical difficulties that would not compromise student's learning*". Additionally, it is essential to make sure that teachers are adequately trained and capable of guiding students through laboratory activities. This could involve creating explainer videos of procedures to facilitate easy following and better understanding, as suggested by one expert.

Finally, the innovation should cater to diverse learning styles and make the manual user-friendly. Respondents pointed out the importance of considering other learning styles and making the material more engaging and less wordy. This could incorporate graphics, cartoons, and other visual aids to make the manual appear friendly and approachable. As one expert noted, *"Make the manual very easy to understand, less wordy, and supply some graphics/cartoons so that it will appear friendly and not just boring paperwork."* Additionally, reviewing the literature on laboratory instruction styles, such as the article by Domin (1999), could provide valuable insights to strengthen and refine the innovation. These improvements would help make the innovation more inclusive, effective, and engaging for a diverse student population.

Teachers' and Students' Feedback on the Innovation

A recurrent theme in students' feedback is the enhanced understanding of gas laws through the visual and interactive nature of simulations. As one student stated, *"The simulation helped me understand the concept of gas laws by closely observing the gas activity whenever there is a change in its environment."* This sentiment underscores how the ability to visualize gas behavior in real time aids comprehension.

Many students highlighted their initial skepticism about replacing traditional experiments with simulations. However, they found the simulations engaging and beneficial for visualizing concepts. One student shared, "*Initially, I was skeptical about using a computer simulation instead of actual lab experiments. However, I found the simulations engaging once I started exploring them. The animations helped me visualize the gas particles' behavior, making concepts like Boyle's Law much clearer."*

Students emphasized the convenience and effectiveness of simulations, finding that the visualizations made the concepts more understandable and comprehensive. Another student noted, "The simulations were much more effective and convenient since they *provided visualizations that helped me understand the concepts better."* Students also appreciated the interactive elements, such as embedded quizzes, which provided immediate feedback and reinforced learning. One student explained, *"I also liked the immediate feedback from the quizzes embedded in the manual."*

Overall, the students' feedback indicates that the simulations facilitated a deeper understanding of gas laws and made learning more engaging and accessible, especially for those adept with technology. One student concluded, *"It is useful to overcome hurdles faced in studying gas laws and contributes to stating accurate and corresponding results of certain experiments."*

Teachers also reported positive experiences with the computer simulation-based laboratory manual. They recognized its value in providing a molecular view of gas behavior, supporting better student information retention. One teacher rated the simulations highly: "*If I rate it from 1 to 5, 1 as poor and five as outstanding, I will rate it as 4."*

Teachers noted a significant benefit of simulations: their ability to cater to different learning styles. Visual learners, in particular, thrived with the simulations, and students who struggled with traditional methods found the new approach refreshing. One teacher highlighted this: "*The interactive nature encouraged students to experiment and explore, which is often difficult to achieve in a conventional lab setting."*

Teachers also observed that the simulation-based approach transformed their teaching methods. One teacher shared, *"The simulation-based approach transformed how I taught gas laws. Previously, I relied heavily on chalk-and-talk and textbook problems, but the simulations brought a new level of engagement."* This transformation improved students' comprehension and increased their enthusiasm for the subject.

However, teachers noted combining simulations with hands-on experiments provided a balanced and comprehensive learning experience. This combination ensured students benefited from the theoretical understanding and practical application of gas laws.

The feedback from students and teachers on using computer simulations in the laboratory manual for gas laws is overwhelmingly positive. Students found the simulations effective, engaging, and convenient, while teachers noted improved student comprehension and enthusiasm.

IV. CONCLUSIONS

A computer simulation-based laboratory manual for gas laws was developed and validated for SHS-STEM students. Expert validation confirmed the effectiveness of the manual's pedagogical approach, content relevance, technology integration, assessment strategies, and teacher support and professional development. This means the manual was found to promote student-centered learning, align with curriculum standards, leverage technology effectively, utilize diverse assessment methods, and provide adequate resources for teachers.

Teachers can use the manual by integrating simulations with traditional teaching methods, providing a balanced and comprehensive learning experience. The simulations cater to different learning styles and can improve student comprehension and enthusiasm for the subject. Moreover, the computer simulation-based laboratory manual for gas laws has the potential to significantly impact the teaching and learning process, transforming the classroom dynamic and improving student learning outcomes.

ACKNOWLEDGEMENT

The researchers would like to express their deepest gratitude to the Cebu Normal University - Graduate School Department for providing the academic foundation and support necessary for the completion of this study, Development, and Validation of a Computer Simulation-Based Laboratory Manual for Gas Laws.

Our heartfelt thanks go to Dr. Joje Mar Sanchez, our esteemed professor, for his invaluable guidance, constructive feedback, and unwavering support throughout the conduct of this research.

We also extend our appreciation to our families and friends for their constant encouragement, understanding, and moral support, which have been a source of strength and inspiration throughout this journey.

This accomplishment is a testament to the collective efforts and contributions of everyone involved, for which we are truly grateful.

REFERENCES

1. Alessi, S. M. & Trollip, S. R.(1991) *Computer Based Instruction: Methods and Development*. New Jersey: Prentice Hall. .

2. Babalola, V. T. (2023). Inclusive skill development for chemistry education programme. *UNESA Journal of Chemical Education*, 12(2), 102-111. https://doi.org/10.26740/ujced.v12n2.p102-111

3. Silver-Bonito, S. J. (2022). Science Education in the Philippines. *Lecture Notes in Educational Technology*, 331–345. https://doi.org/10.1007/978-981-16-6955-2_20

4. Hagverdiyev, N., Sutman, F., & Ugur, N. (2021). The Role of Educational Standards in the Modern Education System.

5. Lee , J., & Abdullah, M. (2011). The intricate world of invisible atoms and complex reactions: Necessitating effective instructional strategies and materials.

6. Mangubat, F.M. (2023). *Anecdotes of university students in learning chemistry: A Philippine context*. Jurnal Pendidikan IPA Indonesia, 12(1), 24-31.

7. Mecampong, C. B. (2017). Status of Chemistry Teaching of the MSU Community High Schools and the National High Schools of Marawi City and Lanao del Sur . *International journal of humanities and social sciences*.

8. Meccawy, M. (2017). Raising a Programmer: Teaching Saudi Children how to Code. *International Journal on Technology Education*, 56-65.

9. Orbe, J., Espinosa, A., & Datukan, J. (2018). Teaching Chemistry in a Spiral Progression Approach: Lessons from Science Teachers in the Philippines. *Australian Journal of Teacher Education*.

10. Shamai, S. (2001). Elementary school students' attitudes towards science and their course of studies in high school. Adolescence. 677-689.

11. Tolentino, J., & Tacubanza, H. (2020). Towards the development of a workbook in fitness testing and basic exercise programming. *Asia Pacific Journal of Multidisciplinary Research*.

12. Wesi, R. (2011). Conceptual Difficulties Associated with Energy. Unpublished doctoral Dissertation.

