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Gas Rules!: An Electronic Strategic Intervention Material for Online Learning: Students' Conceptual Understanding and Perceptions

Celso T. Navarette Jr.[1*], Angelica A. Torrefranca[1], Recson P. Mangolare[1], John Rey E. Celades[1], Rex Vincent V. Mabuting[1], John E. Tugao,[1] Jeffer Jay C. Ybañez[1], Marchee T. Picardal[2], and Joje Mar P. Sanchez[2,3]

[1] *Bachelor of Secondary Science Education, College of Teacher Education, Cebu Normal University*
[2] *Science Education Department, College of Teacher Education, Cebu Normal University*
[3] *Institute for Research in Innovative Instructional Delivery, Cebu Normal University*

*Author to whom correspondence should be addressed; email: celso.navarettejr21@gmail.com

ABSTRACT

This study investigated the effectiveness of the electronic strategic intervention material *Gas Rules!* in teaching Ideal Gas Laws to grade 10 students. A quasi-experimental design was used, with 15 participants in a control group exposed to a modular approach and 15 in an experimental group exposed to the E-SIM. The instruments used for data collection were an entry/exit test and a perceptions questionnaire. Descriptive statistics and non-parametric tests were used for data analysis. Results showed that the modular approach and E-SIM effectively improved students' conceptual understanding of gas laws. However, the E-SIM enhanced students' conceptual understanding more effectively than modules. Additionally, students had positive perceptions of the E-SIM, and there was a significant correlation between their perceptions and conceptual understanding. The study concluded that the *Gas Rules!* E-SIM is an effective and superior tool for teaching gas laws to grade 10 students in basic education. Future research could investigate the impact of E-SIMs on students with different learning styles and abilities.

Keywords: *Conceptual understanding; Electronic strategic intervention material; Ideal gas laws*

INTRODUCTION

Understanding science concepts is vital for science teaching, especially for learners. Consequently, conceptual understanding as a part of the basic competencies umbrella of science learning becomes an inseparable part of the concept of science. As a result, students successfully learn Science (Widiyatmoko & Shimizu, 2018). However, in Chemistry, a discipline where many challenges arise, teachers in classroom practice are algorithmic and emphasize mathematical calculations rather than conceptual and real-world situational examples. To provide meaningful instruction, it is necessary to understand how science concepts are accommodated and processed by students; thus, assessing students' conceptual understanding is essential (Picardal, 2019; Tan et al., 2020; Madaiton et al., 2022).

One best indicator of students' cognitive ability in science is gauging their performance in national and international standardized assessments. In 2018, the Program for International Student Assessment (PISA), the Organization of Economic Cooperation and Development (OECD) countries, achieved level 2 proficiency in science literacy. Therefore, the learners need the skills to identify, recognize, and explain scientific concepts to answer the practical events in their daily life. The results implied a dire need to enhance the learners' conceptual understanding. The Philippines gained a total score in scientific literacy lower than the average score of 489 in the OECD countries and Southeast Asian countries (Schleicher, 2019). On another note, in a study conducted by Trends in International Mathematics and Science Study in 2019 (TIMSS), the country had the lowest standing among 58 countries participating in the international assessment. As for the assessment benchmark, the lowest score should be at least 400, and the nation logged a score lower than that resulting in its lowest rank in the specific domains of Mathematics and Science. Furthermore, the annual National Achievement Test (NAT) in 2019 revealed that Filipino students "gravitate towards low proficiency levels," especially in science, as per Education Secretary Leonor Briones (Hernando-Malipot, 2019). Such underwhelming performance is seconded with thorough evidence in the concurrent educational scenario in the nation, wherein scarcity of classrooms, as well as the paucity of funds, play the primary role in why Science instructional materials were insufficient throughout the country (Salviejo et al., 2014).

To significantly impact learners' performance, there is a need to establish a supportive learning environment to help them learn Science, particularly in Chemistry (Sanchez, 2019; Mangubat & Picardal, 2023), and implement effective instructional interventions regardless of the learning approach adopted (Salviejo et al., 2014). The Department of Education (DepEd) released DepEd Memo. No. 117, series of 2005 entitled "Training Workshop on Strategic Intervention Materials (SIMs) for Successful Learning" supplied for high school educators in the hopes of intensifying the development of intervention materials. This action promotes the use and implementation of SIMs in education. This implementation is further supported by the findings of Suarez and Casinillo (2020), Gabucan and Sanchez (2021), and Samosa (2021) that using SIM is an effective way of teaching 21st-century learners along with colorful, interactive, creative, and innovative ways of presenting it. They also argued that using such intervention materials increases the learners' execution. Thus, SIM helps improve learners' academic performance in the least mastered competencies.

However, due to the current global pandemic, learning was made possible through modular-based instruction. Today's opening of schools was meant for something other than traditional face-to-face learning (Sanchez et al., 2021). UNESCO seconded this resolution, as the organization declared that distance learning could mitigate the spread of the virus. Modular-based learning utilizes self-learning through the distribution of modules as amended by DepEd (Boholano et al., 2022). This study primarily deals with the queuing demands of students upon learning chemistry, specifically on the topic of Ideal Gas Laws. Various researchers have investigated this topic using different teaching strategies, including the conventional macro-micro-symbolic approach (Sanchez, 2017) and multiple online representations (Opona et al., 2022). However, the understanding of teaching the subject needs to be improved using an interactive yet digital remote strategy such as E-SIM. More studies on E-SIM must be conducted to understand its effectiveness in teaching chemistry and other sciences as there are limited studies in the literature, such as De Jesus (2019), Ebojo et al. (2019), Dandan (2022) and Rosal et al. (2022).

With this being presented, the study wanted to determine the effectiveness of using Electronic Strategic Intervention Materials in teaching concepts on Ideal Gas Laws. Specifically, the (a) conceptual understanding of the students' Ideal Gas Laws before and after using the modular approach and *Gas Rules!* E-SIM, (b) the significant difference between and among the level of conceptual understanding of Ideal Gas Laws of the students before and after the use of the modular approach and the said E-SIM, (c) students' level of perception of the effectiveness of using the E-SIM as instructional material, and (d) a significant relationship between the level of conceptual understanding of Ideal Gas Laws after using the E-SIM and the student's level of perception on the effectiveness of using the instructional material.

METHODS

Research Design. The researchers utilized a quasi-experimental research design. This research design includes controlling the independent variable without randomly partitioning research respondents. Primarily, the design was selected because it was necessary to evaluate specific interventions and the possible outcome after their application to non-randomized subjects. Specifically, the researchers employed the tests to gauge students' entry and exit levels on their conceptual understanding of the topic with the E-SIM as an added feature in the instruction.

Research Environment. The locale of this study was an integrated school in a shoreline barangay of a municipality in the province of Cebu. The school had an estimated population of 940, comprising of teachers and students. The cooperating school had synchronous and asynchronous virtual classes and modular learning to cope with the disruption brought about by the COVID-19 pandemic.

Research Respondents. The study respondents came from an integrated school in a municipality's coastal barangay in the Cebu province. The total high school population was 927 students, of which only 170 were Grade 10 students. Thus, the researchers identified a sample size of 30 students participating in the study. The selected size came from two sections of the Grade 10 level. Fifteen students among those who chose to answer printed modules from one section were randomly identified as part of the control group. In contrast, the remaining 15 who chose to answer electronic materials from the other section were randomly identified as the experimental group. The control group was exposed to modular learning, while the experimental group was exposed to the E-SIM-integrated learning approach.

The demographic profiles of the study respondents are presented in Table 1. Most students from the control and experimental groups are 15-16 years old and females. However, most of the students from the control group do not have gadgets nor Internet connectivity, while those from the experimental group have gadgets and Internet connectivity in their homes.

Table 1. Demographic profile of the control group (n=15) and experimental group (n=15)

Profile	Category	Control Group		Experimental Group	
		Frequency	Percentage	Frequency	Percentage
Age	15 years old	6	40.00%	7	46.67%
	16 years old	7	46.67%	7	46.67%
	17 years old	2	13.33%	1	6.67%
Sex	Male	5	33.33%	6	40.00%
	Female	10	66.67%	9	60.00%
Has Gadgets	Yes	4	26.67%	15	100.00%
	No	11	73.33%	0	0.00%
Has Internet	Yes	0	0.00%	15	100.00%
	No	15	100.00%	0	0.00%

Research Instruments. The first instrument was the *Gas Rules!* E-SIM, structured and made by the researchers and validated by three experts. This E-SIM was sent digitally to the experimental group to help them understand the concepts of Ideal Gas Laws. It has five parts: the Guide, Activity, Assessment, Enrichment, and Reference cards, with a scientist named Dr. Kevin, a character created by the researchers to facilitate the interaction between the students and the E-SIM. As an electronic material, *Gas Rules!* have unique and distinctive features such as an interactive and engaging interface, facilitative instruction, and flexible learning accessibility. These features are intertwined in the abovementioned parts. In the *guide card*, Dr. Kevin exposes the students to the lives of Boyle, Charles, and Gay-Lussac to highlight their laws and provide illustrative examples. After being with Dr. Kevin, the students proceed to the *activity card*, wherein they will be given a simulation and guide questions for exploring the application of the laws in their homes. Once they accomplish the activities, their learning is evaluated on the *assessment card*. In this card, they answer various tests, including identification for retention, short response for reasoning, and situations for problem-solving skills. When they finish this stage, they progress to an *enrichment card*, wherein other activities are given to strengthen their acquired learning. YouTube videos and word problems are offered for enrichment. Lastly, the *reference card* completes the ESIM, establishing the objectivity and research-based nature of the material. These parts, including the title page, constitute 39 pages.

The second instrument was the printed module handed out to the control group to help them understand the concepts of Ideal Gas Laws. This module consists of three lessons on Boyle's, Charles's, and Gay-Lussac's laws presented following the prescribed format of DepEd. Each lesson has five parts: What I Need to Know, What I Know, What's In, What's New, What is It, What's More, What I Have Learned, and What I Can Do. These parts primarily have text-based content and fixed examples, and problem sets with no or limited multimedia integration. In *What I Need to Know*, the objectives and guidelines for using the module are presented, and in *What I Know*, the pretest is given to determine the student's knowledge level about the lesson. In *What's In*, the springboard activities were presented, followed by *What's New,* wherein the students explored the lesson by a self-done activity. *What is It* provides the concept done in the earlier action, while *What's More* elaborates the idea by doing another self-done activity. After the series of activities, *What I Have Learned* summarizes the major points of the lesson, and *What I Can Do* offers enrichment activities to deepen their understanding of the lesson. These parts, including the title page, constitute 45 pages.

The other instruments included the entry/exit test and survey questionnaires. The entry/exit test consists of 20 items about the Ideal Gas Laws. The survey questionnaire consists of 12 Likert-scaled items adapted from Salviejo et al. (2014). Experts validated both tools and pilot tested to a similar group of Grade 10 students, resulting in acceptable reliability results.

Data Gathering Procedures. Before the study commenced, the researchers subjected the paper to an ethics review by the University Ethics Committee. After the clearance [782/2021-04 Navarette] was released, transmittal letters were sent to the participating school for approval to conduct the study. Once permitted, informed consent and assent forms were asked from the parents and students, respectively. In turn, the parents and students agreed to participate in the study.

The entry test was conducted and collected via Google Forms. After this entry testing, the cooperating teacher from the abovementioned school implemented the research pedagogies in teaching Ideal Gas Laws, a least mastered competency, to the control and experimental groups. The printed module was given to the control group, while the E-SIM was electronically sent to the experimental group via Google Classroom. The sessions for both groups were asynchronous, meaning that the students went through the lessons using the module or E-SIM independently, with the teacher on standby to answer clarifications. After every week, the students from the control group submitted their handwritten answers through school drop boxes, whereas those from the experimental group submitted them through Google Classroom.

After a month of experimentation, the exit test and survey questionnaire were administered and collected via Google Forms. The online forms were set to be answered using the student's official email address within the set time limit, and Google Forms recorded one response per email.

Data Analysis. The data were obtained via Google Forms and saved in a Microsoft Excel file. Upon checking the characteristics of the data, the researchers employed non-parametric tests to suit the non-normal and more minor sample nature of the dataset. Wilcoxon Signed test, Mann-Whitney U test and Spearman Rho correlation test were used to compare test results and correlated these results with the students' perceptions. To describe the level of perception, weighted means were used. All inferential tests were conducted at a 95% confidence level, and all p-values less than .05 were considered significant.

Ethical Considerations. The ethical considerations observed in this study were confidentiality, honesty, integrity, and respect. Confidentiality and secrecy in handling all the sensitive information the researchers received is the primary goal. Honesty and integrity in reporting all the gathered and interpreted data are at the core of the study. The researchers' utmost concern is respect for all the involved persons in this study. All these ethical considerations were met in the implementation of the study.

RESULTS AND DISCUSSION

Entry and Exit Performance Levels of Grade 10 Students. The student's performance levels in the entry and exit tests are presented in Table 2.

Table 2. Entry and exit performance levels of the students.

Group	Test	H. Median[1]	A. Median[2]	p-value	Description
Control	Entry	15.00	6.00	.000	Below Average
	Exit	15.00	8.50	.000	Below Average
Experimental	Entry	15.00	7.50	.000	Below Average
	Exit	15.00	15.00	1.000	Average

[1] *This is the hypothetical median, equivalent to the 75% standard of the school.*
[2] *This is the actual median obtained in the study.*

The data shows that the control group gained 6.00 and 8.50 in the entry and exit tests, respectively. In the signed test, the group also gained a p-value of .00 for both tests. The performances of the control group in the entry and exit test are below average. The data shows that the experimental group gained 7.50 and 15.00 in the entry and exit tests, respectively. In the signed test, the group also gained a p-value of 0.00 and 1.00 for the entry and exit tests, respectively. The performances of the control group in the entry and exit tests were below average and average, respectively.

Differences between the Entry and Exit Performances. The entry and exit performances were compared using the Wilcoxon signed test. The results of this test are shown in Table 3.

Table 3 shows that under the Wilcoxon Signed test of the control group in their entry and exit tests, they gained the W-value, z-value, and p-value of 34.00, -0.80, and .42, respectively. This finding signifies that the control groups' entry and exit level performance had no significant difference. Moreover, the data shows that under the Wilcoxon Signed test of the experimental group in their entry and exit tests, they gained the W-value, z-value, and p-value of 17.50, -1.96, and 0.03, respectively. This result signifies that the experimental group's entry and exit level performance significantly differed.

Table 3. Wilcoxon signed test results between entry and exit performances.

Group	Median Difference	W-value	z-value	p-value
Control	2.50	34.00	-0.80	.420
Experimental	7.50	17.50*	-1.96	.030

** Significant at p<.05*

Modules are self-contained units of learning that provide a structured approach to teaching complex topics. When teaching the Ideal Gas Laws, modules can be highly effective in improving student comprehension. They provide students with a step-by-step approach to learning and help them build their understanding of the subject through interactive exercises and quizzes (Nuswowati & Purwanti, 2017; Hamid et al., 2021). The significant improvement in exit test scores after using modules suggests that this method is valuable for improving students' understanding of the Ideal Gas Laws, particularly for those who prefer self-paced learning.

Electronic strategic intervention materials (E-SIMs) are computer-based learning tools providing interactive and engaging multimedia learning experiences. E-SIMs can be highly effective when teaching the Ideal Gas Laws, which require much practice for mastery. They provide students with engaging learning experiences (Balazo, 2021; Dandan, 2022; Rosal et al., 2022). The significant improvement in exit test scores after using E-SIMs suggests that this method is a valuable tool for improving students' understanding of the Ideal Gas Laws, especially for those who prefer a multimedia-based approach to learning.

Difference between Median Gains between Control and Experimental Groups. The statistical difference between the median gains between the two groups is provided in Table 4.

Table 4. Mann-Whitney U test results between control and experimental groups

Group	Median Difference	U-value	z-value	p-value
Control	5.00	29.50*	-3.12	.000
Experimental				

** Significant at p<.05*

The data shows that under the Mann-Whitney U-test of the difference in the median gains of the two groups, they gained the U-value, z-score, and p-value of 29.50, -3.12, and .000, respectively. This result signifies that the median gains of the two groups had significant differences. Comparing E-SIMs and modules in teaching gas laws to grade 10 students, E-SIMs are more effective. E-SIMs are computer-based learning tools providing interactive and engaging multimedia learning experiences. At the same time, modules are self-contained units of learning that provide a structured approach to teaching complex topics. E-SIMs offer a more interactive and engaging learning experience that can capture students' attention and interest (Balazo, 2021; Dandan, 2022; Rosal et al., 2022). Moreover, E-SIMs can provide students with immediate feedback, which is crucial for understanding and correcting their mistakes. In contrast, modules are more text-heavy and rely on the student's self-discipline to complete them, making them less engaging and interactive. Therefore, using E-SIMs can be more effective than modules in teaching gas laws to grade 10 students, particularly those who prefer a multimedia-based approach to learning.

Perceptions on the Use of E-SIM. The students' level of perception in the experimental group is presented in Table 5, showing the overall perception of the students on using the E-SIM as instructional material.

Table 5. Level of perceptions on the use of E-SIM

Aspect	No. of Items	Weighted Mean	Description[1]
Understanding concepts	3	2.76	Effective
Reasoning	3	3.07	Effective
Making new concepts	3	2.88	Effective
Application of concepts	3	3.19	Effective
Overall perception	*12*	*2.97*	*Effective*

[1] 1.00-1.75 (Highly ineffective), 1.76-2.50 (Ineffective), 2.51-3.25 (Effective), 3.26-4.00 (Highly ineffective)

The data shows the perception aspects of *understanding concepts*, *reasoning*, *making new concepts*, and *applying concepts*. The results on understanding concepts, reasoning, making new concepts, and applying concepts' mean of the total weighted mean showed that the respondents perceived E-SIM as effective in these four areas. The means of the four categories are 2.76, 3.07, 2.88, and 3.19, respectively. The overall weighted mean of the survey was 2.97, which signifies that the respondents viewed E-SIM as an effective instructional material.

Grade 10 students perceive E-SIMs to be effective in *understanding concepts, reasoning, making new concepts, and application of concepts* due to several reasons. Firstly, E-SIMs are interactive and engaging, which captures the student's attention and interest, making them more likely to stay focused and interested in the material being taught. Secondly, E-SIMs can provide students with immediate feedback, which is crucial for understanding and correcting their mistakes, which in turn can improve their reasoning skills. Thirdly, E-SIMs can present the material in various formats, such as animations, videos, and interactive exercises, which can help students make new connections between the concepts being taught, leading to a deeper understanding of the subject matter. Finally, E-SIMs allow students to apply the concepts they have learned in real-world situations through contextualized activities like simulations and problem-solving tasks, which helps them better retain and use the material (Tabotabo-Picardal & Paño, 2018; Balazo, 2021; Gabucan & Sanchez, 2021; Acedillo et al. (2022); Dandan, 2022; Picardal & Sanchez, 2022; Rosal et al., 2022). Overall, these features of E-SIMs can contribute to grade 10 students perceiving them as an effective tool for learning and understanding gas laws.

Correlation between Students' Performance and Perception. The results of the correlation between the students' median gain performance and perception level towards ESIM are presented in Table 6.

Table 6. Spearman rho results between students' performance and perception

	Rank's Mean	Rank' SD	ρ-value	p-value	R^2 value
Median Gain (X)	7.50	4.16	0.99*	.000	0.980
Perception (Y)	7.50	4.17			

** Significant at p<.05*

Table 6 presents the correlation test result of the respondents' median gain and their perception of using ESIM. It shows that the experimental group had an r, p-value, and R^2 of 0.99, 0.00, and 0.98. This finding indicates a significant relationship between the experimental respondents' median gain and perception of using E-SIM.

This result cohered with the study of Gabucan and Sanchez (2021) and Samosa (2021), stating that positive perceptions and attitudes towards the strategic intervention material can yield high conceptual understanding. The reason why students' perceptions of E-SIM correlate with their performance in gas laws can be explained by several factors. Firstly, students who perceive E-SIMs as a practical learning tool are more likely to engage with the material actively, leading to a better understanding and retention of the concepts. Secondly, receiving immediate feedback through E-SIMs enables students to identify and correct their errors, leading to a more comprehensive understanding of the subject and better performance. Thirdly, students with a positive perception of E-SIMs may invest more time and effort into the material, resulting in better performance outcomes. Lastly, students who view E-SIMs as enjoyable and engaging may develop a more positive attitude towards the subject, leading to greater motivation and interest in the material, which can, in turn, enhance their performance. Overall, students' perceptions of E-SIMs can significantly impact their performance in gas laws, as positive perceptions can foster better engagement, understanding, and retention of the material.

CONCLUSIONS

Electronic strategic intervention material *Gas Rules!* is an effective tool for teaching gas laws to students. Its interactive and engaging format captures the student's attention and interest while providing immediate feedback and opportunities to apply the concepts they have learned. Using multimedia content, animations, and interactive exercises helps students make new connections between the concepts taught, leading to a deeper understanding of the subject matter. Furthermore, students' positive perceptions of the electronic intervention material have been shown to correlate with their improved performance in gas laws. Therefore, E-SIM provides a valuable tool for educators looking to enhance their student's learning experience and understanding of gas laws, particularly for those who prefer a multimedia-based approach to learning.

One limitation of the study is the small sample size. The study only involved a limited number of grade 10 students, which may limit the generalizability of the findings to other populations. Another limitation is that the study only focused on the effectiveness of one particular E-SIM, *Gas Rules!* and did not compare it with other instructional methods. Furthermore, the study only assessed short-term learning outcomes, and is still being determined if the benefits of using E-SIMs will persist over time. Future research could address these limitations by conducting a more extensive study involving a more diverse sample, comparing the effectiveness of different E-SIMs and instructional methods, and assessing the long-term impact of E-SIMs on student learning outcomes. Additionally, future research could explore the impact of E-SIMs on students with different learning styles or abilities to determine if they are equally effective for all students.

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