DEVELOPMENT AND VALIDATION OF E-COMICS FOR TEACHING GENERAL CHEMISTRY

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Abstract - *This study focuses on the creation and validation of contextualized e-comics designed to make General Chemistry more engaging and easier to understand for Senior High School students. Using a descriptive-developmental research design, the e-comics were carefully developed based on a needs assessment, alignment with the K-12 Science Curriculum, and valuable insights from chemistry experts and teachers. Ten experts and ten teachers evaluated the material, ensuring that every aspect—from content accuracy to visual appeal—met high educational standards. A total of 43 STEM students from PHINMA–Araullo University participated in the evaluation of the e-comics during the 2024–2025 academic year. Results from the pretest and posttest revealed clear improvement in students' performance. Before the intervention, 48.8% of students were in the "Very Good" range (19–24) with a mean score of 19.65. After using the e-comics, the percentage of students in the "Outstanding" range (25–30) more than doubled from 14.0% to 34.9%, showing a significant upward shift in achievement. Expert and teacher evaluations also rated the e-comics as "Very Satisfactory," with average scores of 3.40 and 3.60, respectively. This study concludes that the e-comics successfully simplified challenging chemistry concepts while encouraging active learning and motivation. It is recommended to enhance the material further by adding interactive and gamified elements to make the learning experience even more dynamic and relevant.*

Key Words: e-comics; chemistry; visual appeal; narrative appeal;

1.INTRODUCTION

Chemistry often brings to mind dense textbooks, complex equations, and abstract concepts that can feel intimidating. Many students struggle to see how the subject connects to their daily lives, making it difficult to stay engaged. But what if chemistry could be a story — one filled with characters, emotions, and relatable experiences? This is where E-comics come in. The integration of text, visuals, videos, and animations in digital resources offers an interactive platform that successfully engages and retains students' attention. Within science education, the use of comics and cartoons has been gaining popularity among educators seeking creative teaching methods. Despite this, the Philippines still records below-average performance in science, underscoring the necessity for more impactful educational strategies.

The 2022 Programme for International Student Assessment (PISA) results revealed that the Philippines ranked among the bottom three countries with the lowest performance in science. Chemistry is regarded as a challenging branch of science due to its abstract concepts and strong emphasis on mathematical reasoning, making it difficult for many students to grasp. Understanding the conceptual and symbolic dimensions of chemistry is essential for students to develop strong critical thinking skills. In addition, educators highlight the significance of employing systematic and inductive teaching methods, incorporating multiple forms of representation to enhance learning.

2. Review of Related Literature

In presenting topics in ways that are meaningful and relevant to learners' lives, contextualization fosters the development of their skills, knowledge, abilities, and attitudes. By contextualizing and localizing lessons, teachers can tailor instruction to reflect students' prior experiences and real-life situations, making the learning process more adaptable, engaging, and responsive to their needs. This approach promotes flexibility, creativity, and relevance in lesson delivery, ensuring that content aligns with students' levels of understanding.

When students are placed in authentic learning environments—where they can explore, relate to, and interact with resources in their local community, deeper and more meaningful learning takes place. This method also helps both teachers and students connect academic content to the realities of their cultural and social environments, resulting in lessons that are more practical, personalized, and impactful (Torres, 2015).

Contextualization in Learning

Contextualized and localized lessons connect academic content to students' real-life experiences, fostering adaptability, creativity, and deeper engagement (Torres, 2015).

Authentic learning environments allow students to interact with community resources, leading to practical and personalized learning experiences.

Educational Value of Comics

Content Accuracy and Alignment: Creative comics are interactive teaching tools that increase motivation,

empathy, and imagination, while simplifying complex topics through visuals and concise dialogue (Le Doux et al., 2016).

Visual and Narrative Appeal

Comics create an immersive, story-based learning experience, improve memory retention, and foster emotional engagement. Audiovisual comics like KemiToon combine technology and pedagogy to make chemistry more engaging for Filipino learners (Nurdin et al., 2019).

Cultural and Contextual Relevance

Creative writing principles embedded in comics encourage self-expression, creative thinking, and imaginative exploration (Konuk, 2021; Yılmaz, 2018).

Conceptual Comprehension

Comics bridge the gap between abstract science concepts and real-life applications, supporting active learning and critical thinking (Estacio, 2018; Enteria & Casumpang, 2020).

They leverage dual coding theory, combining text and visuals to improve cognitive processing and science literacy (Badeo, 2021).

Application of Knowledge

Comics complement traditional and technology-based teaching methods, especially when laboratory facilities are limited, reducing cognitive load and improving confidence in subjects like chemistry.

Problem-Solving Skills

When combined with Problem-Based Learning (PBL), comics enhance critical thinking and real-world problem-solving skills. Studies show positive effects on motivation, conceptual understanding, and interest in science (Ritonga, 2023; Wati, 2022; Landherr, 2018).

Retention Skills

Comics aid retention by integrating visual and audio elements, which enhance encoding, storage, and retrieval of information (Muzumdar, 2016). Audio-visual comics provide inclusive learning, benefiting students with special needs.

Assessment and Evaluation

Pre-tests and post-tests measure the effectiveness of comics as instructional tools. Post-tests generally result in stronger retention and recall compared to pre-tests (Casati et al., 2019).

T-test analysis confirms significant improvements in student retention and performance, supporting the intervention's effectiveness (Bungsu et al., 2023; Ozcan et al., 2022).

3. Methodology

A developmental research design is a systematic method aimed at exploring how people or groups evolve across different periods, focusing on the influence of factors like age, social class, cohort, and gender on their growth (North Central State College, 2024). It plays a crucial role in areas such as psychology, education, and clinical studies, as it delivers data-driven understanding of developmental trends and results. The e-comics learning materials in Earth and Life Science were developed according to the Research and Development (R&D) procedure proposed by Gay (1990) with the following steps: literature study, planning, development and validation of the prototype, revising the prototype, empirical test, and the final stage is dissemination and implementation.

The evaluation of the E-comics Learning Materials in Chemistry also involved a quantitative approach to analyze their effectiveness, particularly assessing the strengths and limitations of their content and visual design.

This study utilized purposive sampling to identify and select participants who were most relevant to the research objectives. Specifically, the respondents consisted of all 43 Senior High School students officially enrolled in the subject of General Chemistry during the summer term of School Year 2024–2025. This sampling method allowed for a focused implementation of the intervention by ensuring that only those directly involved in the course were included.

For the evaluation component, purposive sampling was also employed in selecting a total of 10 Senior High School science teachers from PHINMA schools, each with a minimum of three years of teaching experience. These teachers assessed the usefulness and effectiveness of the developed e-comics through a standardized evaluation checklist. Additionally, 10

expert validators—each possessing a master's or doctoral degree and at least five years of relevant experience in Science education or related disciplines—were consulted to validate the content accuracy, format, language use, and instructional quality of the vodcast material.

It is worth noting that the study did not control for external factors such as students' previous exposure to

science-related vocabulary development strategies, individual study habits, or prior learning experiences.

Furthermore, the six-month implementation period, spanning from January to June 2025, may have been insufficient to capture the long-term impact of the intervention on students' proficiency in General Chemistry.

Table 1. Frequency Distribution of Respondents

School	Students	English Teachers	Expert Teachers
PHINMA-Araullo University - Main	43	4	7
PHINMA-Araullo University - South	0	3	1
PHINMA-Araullo University - San Jose	0	3	2
TOTAL	43	10	10

The study was conducted at the SHS Department in PHINMA-Araullo University's main campus, Maharlika Highway, Brgy. Bitas, Cabanatuan City, Nueva Ecija.

In educational research, questionnaires are among the most widely utilized methods for collecting data, particularly when examining the effectiveness and quality of instructional materials. By modifying and adopting questionnaires that have been previously validated, researchers can ensure that the tool remains both reliable and relevant, while also tailoring it to the specific needs and context of the study (Creswell & Creswell, 2018).

Studies have shown that well-adapted questionnaires can effectively evaluate critical aspects of learning materials, including the clarity of presentation, contextual appropriateness for students, alignment of learning goals, and organization of content (Liu et al., 2021). These components are essential to the overall quality of instructional resources because they influence student understanding, motivation, and the perceived value of the material (Kimmons & Hall, 2018).

The four-point Likert scale is a common choice in such evaluations because it eliminates the neutral option and encourages respondents to provide more decisive feedback. This type of scale is particularly useful for rating elements such as clarity, relevance, and structure, enabling researchers to gather more precise data for analysis (Joshi et al., 2015).

Recent literature also underscores the importance of using multiple questionnaires to cover various dimensions of instructional materials. For example, one set might focus on evaluating content and structure, while another set measures usability, learner experience, and satisfaction (Tadesse & Gillies, 2021). This layered approach allows for a more detailed and reliable assessment.

As part of best practices, any adapted instrument must undergo content validation and pilot testing to confirm its suitability for the intended context or material type (Hernández-Nieto, 2020). For instance, Bulalayao's (2011) e-

comics questionnaire offers a strong base for evaluating digital instructional resources, and adapting it with a well-defined Likert scale ensures alignment with modern evaluation practices.

The quality of the e-comics was evaluated through the participants' assessments during the empirical testing phase. Furthermore, the students' visual skills were assessed following the development of the e-comics materials. The collected data were then processed using frequency distribution and weighted mean.

The data were recorded and summarized to create a frequency distribution, which was then organized into tables. Additionally, the weighted mean of each item was calculated to generate the verbal interpretation of the respondents' evaluations of the e-comics learning materials in General Chemistry.

The study involved Grade 12 STEM students enrolled in General Chemistry at PHINMA-Araullo University. The data were gathered using survey questionnaires and evaluation forms, with a 4-point Likert scale used to assess students' perceptions, engagement, and comprehension of the e-comics resources.

Additionally, a pre-test and post-test were administered to measure students' academic performance and evaluate the effectiveness of the e-comics.

Once the data were collected, they were compiled and encoded using appropriate statistical software such as SPSS or MS Excel. The data were then cleaned to ensure completeness and consistency, and responses were categorized according to the evaluation criteria. To determine students' overall perception of the effectiveness of the e-comics, a weighted mean was calculated using the formula: , where represented the weighted mean, was the frequency of responses, and denoted the Likert scale value ranging from 1 to 4.

The weighted mean results will be interpreted using the following scale:

Verbal Description	Scale	Weighted Mean Range
4	Strongly Agree	3.26-4.00
3	Agree	2.51-3.25
2	Disagree	1.76-2.50
1	Strongly Disagree	1.0-2.49

Table 2. Scales and Interpretation

In this study, Grade 12 STEM students enrolled in General Chemistry at PHINMA-Araullo University participated as respondents. Data collection involved administering survey questionnaires and evaluation forms, using a 4-point Likert scale to assess students' perceptions, engagement, and comprehension of the e-comics.

Furthermore, a pre-test and post-test will be used to evaluate students' academicperformance and assess the effectiveness of the comic resources.

To determine whether there is a significant difference in students' performance before and after using the e-comics resources, a paired sample t-test will be conducted. This statistical test is appropriate for comparing the means of two related groups — the pre-test and post-test scores — to identify any significant changes in academic performance. The paired t-test formula is, where represents the t-statistic, is the mean difference between pre-test and post-test scores, denotes the standard deviation of the differences, and is the number of paired samples.

A 0.05 significance level is used to determine if the results are statistically significant. If the computed p-value is less than 0.05, it will indicate a significant improvement in students' performance after using the comic resources.

Additionally, descriptive statistics were applied to analyze students' understanding of General Chemistry concepts based on four specific criteria: conceptual comprehension, application of knowledge, problem-solving skills, and retention of concepts. The weighted mean will be calculated to measure the average response from the 4-point Likert scale questionnaires, providing a clear representation of student perceptions.

Standard deviation is used to assess the variability of responses, offering insights into the consistency of student feedback. This quantitative approach will provide a comprehensive understanding of how students perceive and engage with the comic resources.

The results from both the t-test and descriptive analysis will be used to conclude the effectiveness of the e-comics. The t-test will provide objective evidence on whether the comics significantly enhance students' academic performance, while the descriptive analysis will offer a detailed view of student perceptions and learning experiences.

Based on these findings, the study presents evidence-based recommendations for improving and further integrating comic resources into Chemistry instruction.

4. Results and Findings

Pre–Planning Phase

The pre-planning phase in this study involved the careful selection and organization of topics in General Chemistry for Grade 12 learners. The researcher deliberately reviewed and chose the best lessons or topics, opting not to follow consecutive lessons but instead selecting ten distinct topics. This approach aligns with the principle of pre-planning as a foundational step that establishes clear goals and expectations, thereby setting the stage for effective teaching and learning.

Planning Phase

The planning phase for developing e-comic resources to teach General Chemistry, particularly the budgeting lesson, involves a thoughtful and organized process. During this stage, the researcher carefully identifies the scope and sequence of the lesson and selects textbooks, references, and other instructional materials that relate to the topic.

To make the learning experience more engaging and effective, activities are designed to address eight different learning styles—Visual-Spatial, Bodily Kinesthetic, Musical, Linguistic, Logical-Mathematical, Interpersonal, Intrapersonal, and Naturalistic. This approach helps ensure that the e-comic resources connect with a wide variety of learners, making complex concepts like budgeting in chemistry labs easier to understand and more relatable.

Recent studies support the importance of this kind of detailed planning when creating educational materials. Research shows that aligning content with curriculum standards and considering learners' needs leads to better teaching outcomes (Rivera & Turno, 2024). Including different learning styles in lesson design also helps boost student engagement and understanding (Gardner, 2020). In addition, e-comics have been found to help students visualize and remember difficult science concepts by combining storytelling with visuals (Cook & van Hest, 2024; Novianti & Putra, 2020).

Overall, having a clear plan with a well-organized scope, relevant references, and varied activities creates a more meaningful and effective learning experience, especially for challenging subjects like General Chemistry.

Developing Phase

In this phase, the researcher carefully designed and developed an e-comic tailored to help students better understand key general chemistry topics. The content focused on ten important areas, including intermolecular forces, kinetic molecular theory, solution properties, stoichiometry, thermochemistry, and laws of thermodynamics. To make these complex concepts more accessible and engaging, the e-comic combined clear explanations with colorful illustrations and relatable storylines that connect chemistry to everyday life.

The materials were created with the learners' diverse needs in mind, using original graphics alongside carefully selected images to keep students interested and motivated.

Feedback from chemistry teachers was also incorporated to ensure accuracy and clarity. Overall, this phase aimed to produce an interactive and enjoyable learning tool that supports students in grasping challenging chemistry topics through a fresh, visual, and student-friendly approach.

The use of comics and e-comics as educational tools in chemistry has gained attention for their ability to make complex scientific concepts more accessible and engaging to students. Comics combine visual elements with narrative storytelling, which helps in breaking down difficult topics into digestible and relatable content. For example, a recent study demonstrated that self-made comic zines effectively engaged high school chemistry students by presenting information in a visually appealing and easily understandable format, improving both motivation and scientific comprehension (ACS Publications, 2024). This aligns with the approach of integrating colorful illustrations and relatable storylines to connect chemistry concepts to everyday life.

Furthermore, e-comics have been shown to significantly enhance students' scientific literacy and understanding of chemistry topics through interactive narratives and visual illustrations.

A quasi-experimental study on e-comic media based on scientific literacy reported medium-level improvements in students' learning outcomes and high satisfaction rates from both students and teachers, highlighting the effectiveness of e-comics in supporting complex scientific learning (USEJ, 2024). This supports the idea of designing materials that cater to diverse learner needs by combining original graphics with carefully selected images to maintain interest and motivation.

In addition, electronic comic media fosters a positive learning atmosphere by encouraging independent exploration of chemical concepts, increasing student motivation, and reducing anxiety toward chemistry. Research has shown that e-comics not only improve cognitive understanding but also positively influence students' attitudes and willingness to engage actively in learning activities (East Asian Journal of Multidisciplinary Research, 2025). Incorporating feedback from chemistry teachers ensures the accuracy and clarity of content, which is crucial for educational effectiveness.

Lastly, multimedia tools that integrate visual, interactive, and narrative elements are essential in chemistry education to help students build mental models of abstract phenomena such as molecular interactions and thermodynamics. Multimedia designed with principles such as multiple representations, dynamic interactivity, and cognitive load reduction can improve students' comprehension and create a positive impression of chemistry as a subject (International Journal of Instruction, 2020; Jurnal Penelitian Pendidikan, 2023). This underlines the importance
of an interactive and enjoyable learning tool like an e-comic to support student learning in challenging chemistry topics.

Evaluation Phase

After gathering all necessary materials for the development of e-comic resources in General Chemistry, the researcher proceeded to modify and adapt the evaluation tools to fit the nature of the instructional material. The evaluation process was guided by the standards set in the Division Memorandum No. 167, s. 2021 of Nueva Ecija, titled Evaluation Rating Sheets for Locally Developed Learning Resources.

This ensured comprehensive coverage of all essential aspects of quality. The developed e-comic resources were then evaluated by General Chemistry teachers and subject matter experts using specific criteria, namely: Content Quality; Format including Text, Illustrations, Design, and Layout; Presentation and Organization; and Accuracy and Up-to-dateness of Information.

In the context of science education, involving subject matter experts and experienced teachers in the evaluation process is crucial. Studies have shown that expert validation helps maintain content accuracy and pedagogical appropriateness, while teacher feedback ensures the material's usability and engagement for students (Rodriguez & Santos, 2023). This collaborative approach enhances the instructional resource's credibility and effectiveness.
Moreover, adapting evaluation tools to fit the unique characteristics of the instructional material—such as an e-comic—allows for more precise assessment.

For instance, evaluation criteria for e-comics must consider not only factual correctness but also the quality of illustrations, narrative flow, and interactive elements that support student engagement and comprehension (Lee & Kim, 2022). This tailored evaluation approach aligns with best practices in educational technology development, ensuring that the final product is both pedagogically sound and appealing to learners.

Finalization Phase

During the finalization phase, the researcher revised the differentiated learning material based on the feedback and recommendations provided by the respondents and experts. As a result, the learning competencies and lesson objectives were refined to align with the SMART criteria—specific, measurable, attainable, realistic, and time-bound.

The finalized material was thoughtfully designed to be well-structured and clearly formulated, promoting critical thinking and deeper conceptual understanding.

Its presentation and format were engaging and visually appealing, capturing learners' interest through diverse and creative differentiated activities tailored to address eight distinct learning styles. Furthermore, the integration of interdisciplinary elements aimed to foster higher-order thinking skills, enhancing students' strengths while addressing their areas for improvement.

Results of Evaluation

The panel included faculty members with expertise in General Chemistry and curriculum development. The evaluation centered on key criteria such as content quality; format, including the appropriateness of text, illustrations, design, and layout; presentation and organization; and the accuracy and up-to-datedness of scientific information.

The results from both the teacher-evaluators and experts provided a comprehensive perspective on the instructional value and academic soundness of the developed e-comic. Their collective feedback indicates that the material is well-aligned with the university's curriculum standards and effectively supports student learning.

Overall, the e-comic was found to be scientifically accurate, pedagogically relevant, visually appealing, and capable of fostering learner engagement and deeper understanding of General Chemistry concepts.

Significant difference between the pretest and posttest of the experimental group

Based on the results of the pretest and posttest administered to 43 students, there was a notable improvement in their performance in General Chemistry after using the developed e-comics resources. In the pretest, the majority of students (48.8%) scored within the "Very Good" range (19–24), with a mean score of 19.65, also categorized as "Very Good." In the posttest, the percentage of students in the "Outstanding" category (25–30) more than doubled from 14.0% to 34.9%, indicating a significant upward shift in performance. At the same time, there was a slight decrease in the number of students scoring "Very Good" and "Fair," suggesting that several learners moved up into the highest performance bracket after the intervention.

Contextualized instructional materials have been widely recognized for their ability to enhance student understanding and academic performance by relating abstract concepts to real-life situations. According to Herrington, Reeves, and Oliver (2018), learning environments promote deeper engagement and

meaningful learning, which leads to improved student outcomes. This supports the observed improvement in students' General Chemistry performance after using the developed e-comic, as the resource likely made complex chemistry concepts more relatable and easier to grasp. Pretest-posttest assessments are commonly used to measure the effectiveness of educational interventions.

According to Creswell (2017), a notable shift in posttest scores compared to pretest results is a strong indicator of learning gains attributable to the intervention. The doubling of students in the "Outstanding" category and the upward movement from "Very Good" and "Fair" categories in this study exemplify such positive learning gains, confirming the e-comic's impact on student achievement.

Moreover, the mean score increased from 19.65 to 21.12, both within the "Very Good" range, but the upward trend reflects an improvement in students' mastery of General Chemistry concepts. This improvement suggests that the use of the e-comics helped students understand the content more effectively, reinforcing learning in a way that traditional materials may not have achieved.

The Results of the Paired samples T-test

The results of the paired samples t-test reveal a statistically significant difference between the pretest and posttest scores of students in the experimental group, with a p-value of 0.030, which is less than the 0.05 level of significance. The mean score increased from 19.65 (pretest) to 21.12 (posttest), indicating a measurable improvement in students' performance after the implementation of the e-comics in General Chemistry.

The computed t-value of -2.236 further supports the conclusion that the difference in scores is not due to chance. This suggests that the use of the developed e-comic had a positive and significant impact on student learning outcomes, enhancing their understanding and mastery of the subject matter.

Therefore, the data confirms that the e-comic is an effective supplementary instructional material in improving students' academic performance in General Chemistry. Numerous studies have demonstrated the positive impact of multimedia and instructional materials on student learning outcomes, particularly in science education.

For instance, research by Sung, Chang, and Yang (2015) found that the integration of digital comics in science classes significantly improved students' understanding and retention of complex concepts, as evidenced by increased posttest scores compared to pretest results. Similarly, a study by Hwang and Chang (2016) reported that e-learning tools, which connect content to real-life scenarios, effectively enhance student engagement and academic performance.

The statistically significant improvement in mean scores from 19.65 to 21.12 in this study, supported by a p-value of 0.030 and a t-value of -2.236, aligns with these findings, indicating that the developed e-comic served as an effective supplementary instructional material. This corroborates the assertion that incorporating interactive and contextually relevant resources fosters deeper comprehension and mastery of General Chemistry topics, ultimately leading to measurable gains in student achievement.

Evaluators shared that the overall content of the pretest and post test for the e-comics truly met its objectives and made a positive impact on students.

Suggestions and Recommendations for Enhancement

As for the recommendations of the science teachers and subject matter experts from PHINMA Araullo University regarding the developed e-comic in General Chemistry, the respondents acknowledged that the material is a highly valuable resource that could serve as an effective supplemental tool in future chemistry instruction. According to the evaluators, the e-comic presents abstract concepts in a more visual, relatable, and engaging manner, making it suitable for learners with diverse learning preferences.

RECCOMMENDATIONS

1. Future versions of the e-comic should be periodically reviewed and updated based on feedback from students, teachers, and experts to ensure content relevance, scientific accuracy, and alignment with evolving educational standards.

2. The developed e-comics should be integrated into General Chemistry instruction as a supplementary learning material for both enrichment and remediation purposes. Its strong alignment with educational standards and learner-centered design makes it particularly suitable for diverse classroom

settings, including modular and remote learning environments.

3. Teachers should receive guidance or training on how to effectively integrate the e-comic into classroom instruction to maximize its pedagogical benefits. Also, to further validate the effectiveness of the e-comics, similar studies should be conducted across different schools, grade levels, and science subjects, allowing for broader application and continuous improvement of the material.

4. Include interactive elements such as clickable vectors, animations, or mini-quizzes to increase learner engagement and deepen conceptual understanding, especially for digital formats. Also, conduct training for teachers on how to effectively integrate the e-comic into their teaching strategies to maximize its impact on student learning outcomes.

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Ms. Subaldo is a strong advocate of active and transformative learning, firmly believing in the power of education to shape learners into confident, articulate, and critical thinkers. With a focused expertise in General Chemistry, she combines academic rigor with practical, real-world applications to ensure meaningful learning experiences for her students.

Aligned with the mission of **PHINMA Education, Ms. Subaldo** remains deeply dedicated to making quality education accessible, relevant, and life-changing for every Filipino learner, consistently striving to inspire and empower the next generation.