

## ICT Applied to Scientific Education at University

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### Abstract

Information and Communication Technologies (ICT) significantly enhance science education by making learning interactive, accessible, and engaging. This study explores the integration of the molecular visualization software Avogadro into an introductory Chemistry course at the University of Huelva. By facilitating three-dimensional visualization of molecular structures using Avogadro, the students' spatial comprehension and understanding of chemical concepts improved. Data collected via surveys, motivation scales, and academic performance indicated high student satisfaction (85% average) and increased motivation. These findings highlight ICT's potential to create dynamic learning environments, enhance student-teacher interactions and foster deeper comprehension of scientific content.

*Keywords: Science education, molecular visualization, university teaching, ICT integration, educational effectiveness.*

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## TIC Aplicada a la Educación Científica en la Universidad

### Resumen

Las Tecnologías de la Información y Comunicación (TIC) enriquecen notablemente la educación científica, haciendo que el aprendizaje sea interactivo, accesible y atractivo. Este estudio examina la incorporación del software de visualización molecular Avogadro en un curso introductorio de Química en la Universidad de Huelva. Al permitir la visualización tridimensional de estructuras moleculares, Avogadro mejoró la comprensión espacial de los estudiantes y facilitó el aprendizaje de conceptos químicos complejos. Los datos obtenidos mediante encuestas, escalas de motivación y desempeño académico revelaron un alto grado de satisfacción estudiantil (85% en promedio) y un incremento notable en la motivación. Los resultados subrayan el potencial de las TIC para crear ambientes educativos dinámicos, fortalecer la interacción profesor-alumno y mejorar sustancialmente la comprensión de contenidos científicos.

*Palabras clave: Educación científica, visualización molecular, enseñanza universitaria, integración TIC, efectividad educativa.*

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## Introduction

Information and Communication Technologies (ICT) have revolutionized educational practices, transforming traditional classroom environments into dynamic learning spaces. Science education, particularly Chemistry, greatly benefits from integrating ICT as these technologies offer students interactive experiences, facilitate real-time data analysis, and improve engagement. Traditional methods relying solely on textbooks and static visual aids have become insufficient for fully preparing students for contemporary scientific challenges.

Molecular visualization software, such as Avogadro, presents an innovative approach to addressing these educational gaps. Avogadro is an advanced, user-friendly molecule editor and visualizer utilized widely across disciplines including computational chemistry, molecular modelling, and materials science [Kapla et al., 2012; Mayorkas et al., 2011; Mera-Adasme et al., 2011]. Its robust visualization capabilities enable students to effectively interpret complex molecular structures and concepts. It is freely accessible at <https://avogadro.cc>

This study aims to demonstrate the positive educational impacts of integrating ICT tools, specifically molecular visualization software, into university-level Chemistry teaching. The research examines students' perceptions, motivation levels, and academic performance to assess the effectiveness of ICT in enhancing scientific education.

## Methodology

### *Participants (students)*

The study was conducted within an introductory Chemistry course at the University of Huelva, Spain. A total of 41 undergraduate students from diverse degree programs, primarily Environmental Sciences and Geology, participated.

### *Analysis of the data of this study*

Data collection involved the administration of structured questionnaires designed to gauge student satisfaction and motivation levels. Additionally, the Achievement Motivation Scale (AMS) was employed to quantify students' academic motivation [Boak 2024]. Academic performance was measured through exam results and course exercises, providing objective data on student achievement. Statistical analysis was performed using SPSS and Origin software packages to determine correlations and assess the effectiveness of ICT integration on student outcomes. Descriptive and inferential statistical techniques were applied to validate the reliability and interpretability of the results.

## Results and Discussion

An innovative project is a strategic plan focused on creating new ideas, products, or services aimed at advancing curricular training, education, and technology, with the goal of enhancing the quality of the teaching-learning process [Martínez Sanahuja, 2019]. Such a project should demonstrate a clear, positive impact on education.

The introductory Chemistry course addressed foundational topics including atomic structure, the periodic table, chemical bonding, states of matter, solutions, gases, and chemical thermodynamics, carrying 9 ECTS credits. The course structure comprised theoretical lectures, problem-solving exercises, and practical laboratory sessions.

Analysis of collected data indicated a normal distribution of student achievement levels, suggesting consistent academic performance compared to previous academic cycles. The integration of Avogadro software significantly enhanced students' spatial visualization and comprehension of molecular concepts, as illustrated in Figure 1, depicting a benzene molecule ( $C_6H_6$ ).

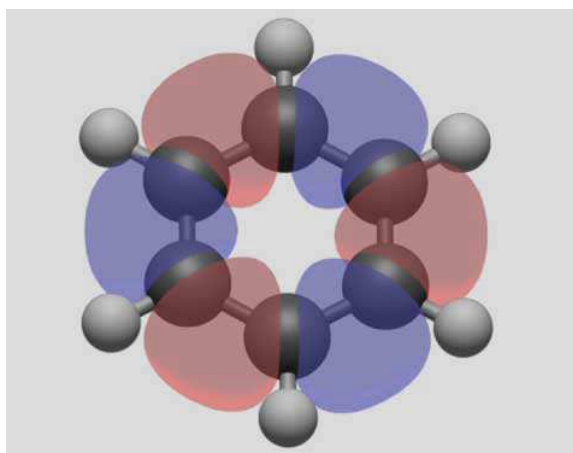


Figure 1. Molecular structural simulation with Avogadro. Source: <https://avogadro.cc>

Our findings revealed that the satisfaction survey demonstrated high student satisfaction, with an average rate of 85%, as shown in **Table 1**. Students from Environmental Sciences exhibited a slightly higher satisfaction rate (90%) compared to those from Geology (80%). Additionally, results from the Achievement Motivation Scale reflected increased student motivation and engagement throughout the course.

Table 1. Comparison of satisfaction rates for the Chemistry course across different degree programs

Degree Program	Satisfaction Rate
Environmental Sciences	90%
Geology	80%

These results underscore the effectiveness of ICT tools such as Avogadro in fostering deeper student engagement and improving educational outcomes in Chemistry. The findings affirm the strategic value of ICT integration in enhancing the teaching-learning process.

## Conclusion

The findings of this study clearly demonstrate the transformative potential of ICT in science education, notably through the integration of speciali-

zed software like Avogadro. ICT tools effectively enhance student engagement, motivation, and comprehension of complex scientific concepts, thereby significantly improving the educational experience.

However, the successful integration of ICT requires adequate teacher training and consistent student access to technological resources. Future studies should explore further applications of molecular visualization software in advanced Chemistry courses and other scientific disciplines. Overall, Avogadro has proven to be an effective platform for teaching chemical structure visualization, offering substantial promise for broader educational innovation and effectiveness.

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