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THE THEORETICAL BASIS OF TEACHING CHEMISTRY TO STUDENTS BASED ON DIGITAL EDUCATIONAL PLATFORMS

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ABSTRACT

The rapid development of digital technologies has significantly influenced the methodology and practice of teaching chemistry in higher educational institutions. This article examines the theoretical foundations of integrating digital educational platforms into the chemistry curriculum. It explores how digital platforms such as Moodle, Google Classroom, and virtual laboratories provide an innovative environment for active learning, promoting student engagement, independent research, and collaborative problem-solving. By applying modern pedagogical theories such as constructivism, cognitive load theory, and differentiated instruction, this study highlights the pedagogical advantages of digital platforms in fostering a deeper conceptual understanding of complex chemical processes. Furthermore, the article addresses the role of digital tools in the continuous assessment and feedback process, contributing to students' autonomous learning capabilities. It also discusses the challenges associated with implementing digital educational platforms, such as access to technology and the development of appropriate digital content, as well as potential solutions. The findings underscore the necessity of teacher professional development and the alignment of digital tools with curriculum objectives to enhance the overall effectiveness of chemistry education.

Key words: digital educational platforms, chemistry education, theoretical frameworks, e-learning in science, online learning environments, educational technology, virtual laboratories, student engagement, interactive learning tools,

pedagogical approaches in chemistry, multimedia resources, stem education, personalized learning, collaborative learning

INTRODUCTION

In recent years, integrating digital educational platforms has revolutionized teaching and learning across various academic disciplines, including chemistry. The rapid advancement of technology has provided educators with new tools to enhance students' engagement, comprehension, and mastery of complex scientific concepts. Digital platforms like Moodle, Google Classroom, and other interactive learning environments offer unique opportunities to bridge theoretical knowledge with practical application through simulations, visualizations, and real-time data analysis.

Teaching chemistry, a subject inherently characterized by abstract and often difficult-to-visualize concepts can greatly benefit from these digital innovations. Traditional methods of instruction, while valuable, sometimes fail to accommodate diverse learning styles and do not always provide interactive, student-centered approaches that foster deeper understanding. By contrast, digital platforms enable instructors to employ a more personalized and adaptive pedagogical approach, where students can access a range of multimedia content and participate in virtual laboratories, enhancing all their engagement and independent learning capabilities.

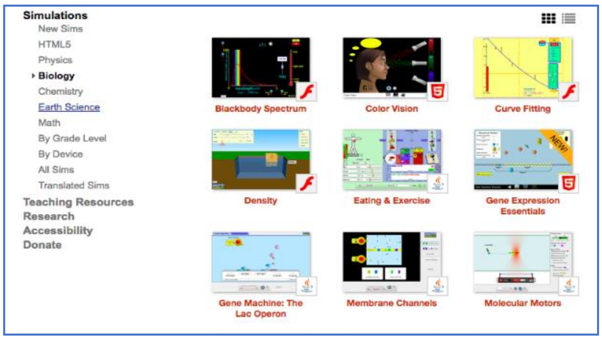
Besides that, teaching of chemistry requires a deep understanding of molecular structures, chemical reactions, and the periodic table, among other complex concepts. Historically, traditional classroom settings and laboratory experiences have been central to this understanding. However, with the increasing accessibility of digital educational platforms, these foundational elements of chemistry education can now be delivered in a more flexible, personalized, and engaging manner. These platforms offer tools such as virtual labs, interactive exercises, and instant feedback mechanisms, all of which contribute to a richer learning experience.

MATERIAL AND METHODS

Nowadays, the role of digital educational platforms in teaching chemistry to students is transformative, offering several advantages that enhance both learning and teaching experiences. Chemistry concepts, especially abstract topics like atomic structure, molecular bonding, and thermodynamics, can be difficult for students to grasp through traditional textbooks alone. Digital platforms provide interactive simulations and visualizations that make these topics more tangible. Chemistry concepts, especially abstract topics like atomic structure, molecular bonding, and thermodynamics, can be difficult for students to grasp through traditional textbooks alone. Digital platforms provide interactive simulations and visualizations that make these topics more tangible.

For example, platforms like PhET simulations and virtual lab environments allow students to manipulate chemical elements, observe reactions, and conduct experiments in a risk-free, virtual space. This hands-on interaction aids in deeper conceptual understanding. (1-picture)

a)



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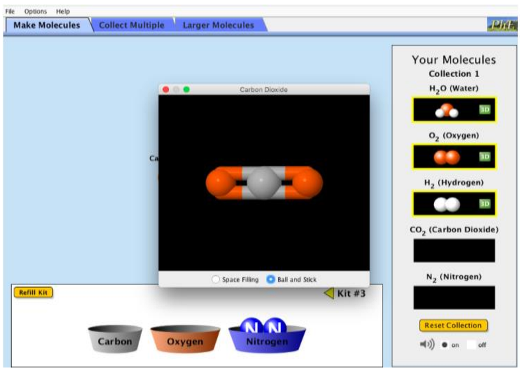

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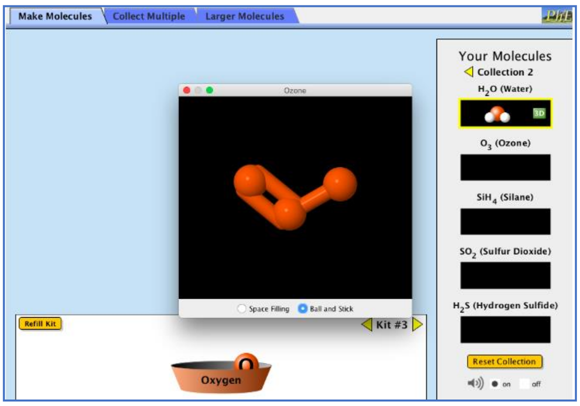

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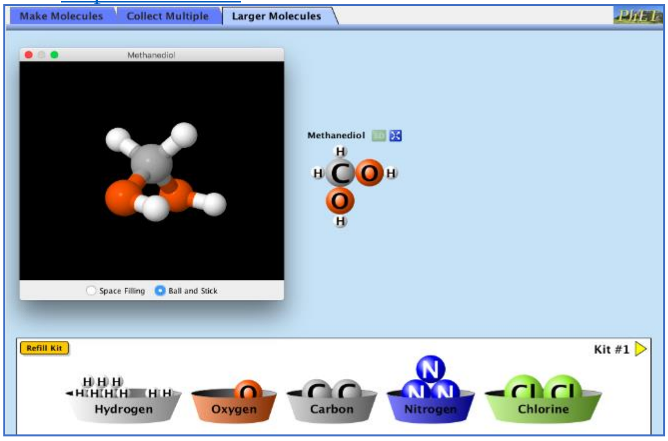
Journal of Advanced Scientific Research (ISSN: 0976-9595)
Vol.5. Issue 10 page 126
Impact factor 9



e)

1st picture. PhET simulations virtual lab

Thus, digital educational platforms such as Moodle, Canvas, and Google Classroom offer anytime, anywhere access to learning materials. Students can review lectures, participate in forums, and complete assignments at their own pace, promoting self-regulated learning.

This flexibility is particularly beneficial for students with different learning styles, allowing them to revisit complex topics as needed or engage in additional practice through quizzes and exercises. Platforms incorporate features such as self-assessment quizzes, automated feedback, and adaptive learning paths. These elements encourage students to take control of their learning process by identifying their strengths and areas for improvement. Chemistry problems often require critical thinking and step-by-step problem-solving. Digital platforms can break down complex problems into smaller tasks, offer hints, and provide immediate feedback, fostering independent learning skills.

Modern platforms integrate tools for peer collaboration, such as discussion boards, group projects, and collaborative assignments. Chemistry learning often benefits from discussion and sharing of ideas, especially when solving complex chemical equations or analyzing experimental results. Platforms offer built-in communication tools like forums, chats, and video conferencing to promote engagement between students and instructors, which enhances learning by facilitating ongoing support and clarification. With digital platforms, assessments can be

Journal of Advanced Scientific Research (ISSN: 0976-9595)
Vol.5. Issue 10 page 127
Impact factor 9
continuous and formative, allowing teachers to track progress and provide timely feedback. Features such as automated grading, progress tracking dashboards, and analytics give insights into student performance. Students receive immediate feedback on assignments and quizzes, which is crucial for subjects like chemistry, where understanding evolves progressively.

Digital platforms provide access to vast libraries of multimedia content including instructional videos, e-books, scholarly articles, and interactive quizzes. Platforms like Khan Academy and YouTube channels dedicated to chemistry tutorials supplement learning. These resources often include open educational resources (OERs) and chemistry-specific databases, which can be tailored to various levels of expertise and curriculum requirements.

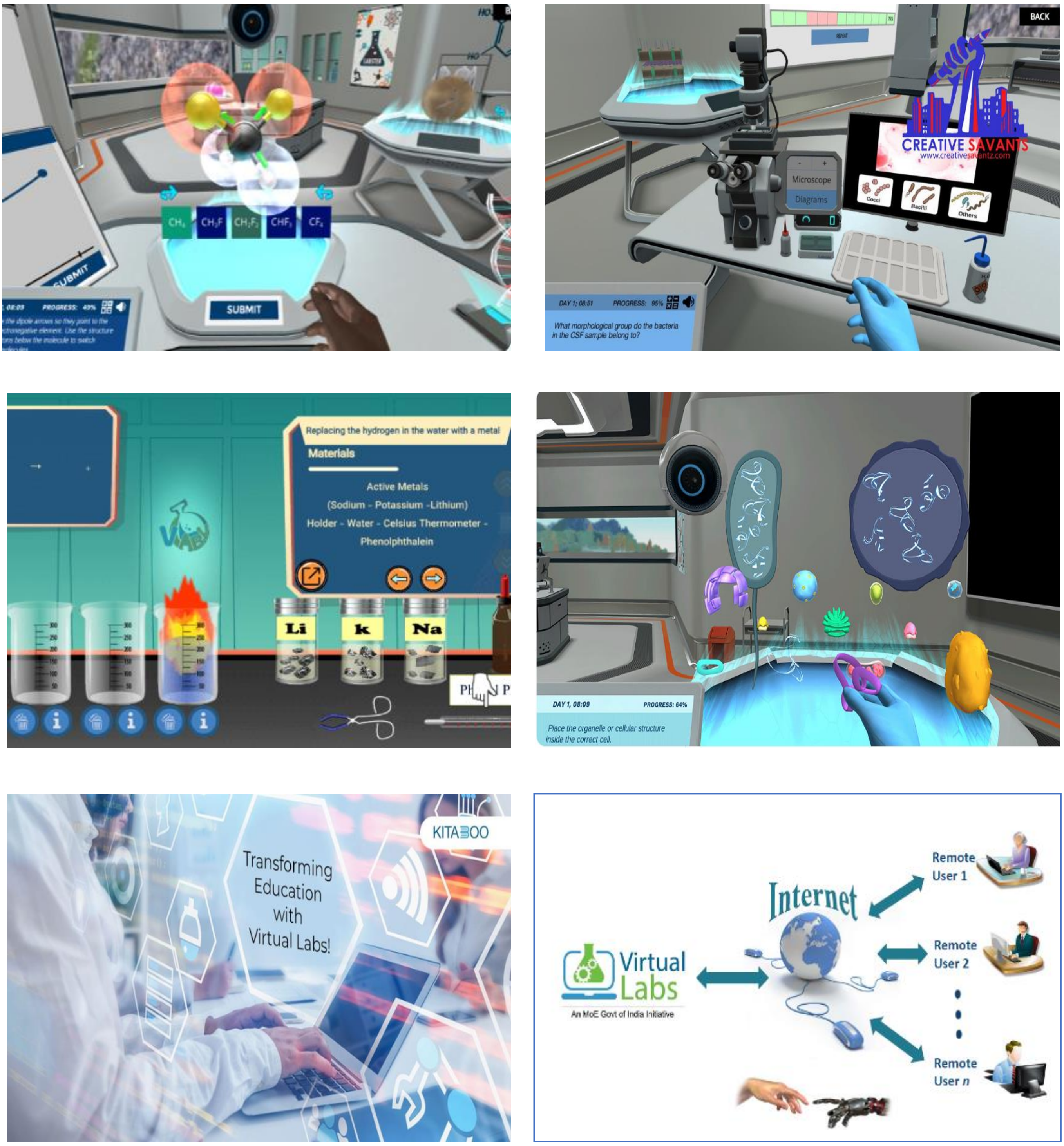
Digital platforms can adapt content delivery to the learner's pace and performance through personalized learning paths. This ensures that students are not overwhelmed and can master foundational concepts before moving on to more advanced topics. Teachers can customize assignments, lessons, and assessments based on the individual needs of students, allowing for differentiation and targeted intervention where needed. Digital platforms reduce the need for printed textbooks, laboratory materials, and physical resources, making chemistry education more environmentally friendly**.** Virtual labs, for instance, eliminate the need for actual chemicals, reducing waste and potential hazards. Digital platforms enable remote learning, making chemistry education accessible to students in geographically isolated areas or those unable to attend traditional in-person classes. These platforms support inclusive education by offering adjustable features (e.g., video captions, and text-to-speech tools) to accommodate students with diverse learning needs and disabilities.

Currently, Moodle, Google Classroom, or Canvas is used to host course materials, assessments, and communication tools. Platforms include simulation tools like ChemCollective, PhET simulations, or specialized chemistry apps for interactive

Journal of Advanced Scientific Research (ISSN: 0976-9595)
Vol.5. Issue 10 page 128
Impact factor 9

experiments. Multimedia resources, including video tutorials (e.g., YouTube or Khan Academy), digital textbooks, and interactive 3D molecular modeling tools.

So, we have analyzed several teaching chemistries to students based on digital educational platforms. Teaching chemistry to students using digital educational platforms requires leveraging specific methods that capitalize on the strengths of technology to enhance learning. The blended learning method combines traditional classroom instruction with online resources and tools. Chemistry lessons can be divided into in-person laboratory sessions and digital learning activities such as online lectures, quizzes, and simulations. Students can watch video tutorials or engage with interactive multimedia content on platforms like Moodle or Google Classroom before coming to the classroom for hands-on lab work. This method allows for better preparation and maximizes practical lab time. In the flipped classroom method, students first learn new content online by watching pre-recorded lectures or completing readings and interactive activities. The time in class is then dedicated to discussion, problem-solving, and hands-on experiments. Platforms such as Canvas or Edmodo can host video lessons on topics like chemical reactions or molecular structures, and in-class activities can involve group work or performing experiments based on online materials. Virtual labs are a cornerstone of teaching chemistry digitally. They simulate real-life laboratory environments, allowing students to perform experiments in a safe, controlled digital space. Platforms like Labster, and ChemCollective (2nd picture) provide high-quality virtual labs where students can practice chemical reactions, titrations, and explore molecular interactions without the need for physical lab equipment. Simulations are also highly useful for abstract or dangerous experiments that may be difficult to perform in a physical lab.



Picture 2. Labster and Chemcollective platforms

Gamification methods introduce game-like elements into chemistry education to motivate students and increase engagement. By incorporating quizzes, competitions, leaderboards, and rewards, students are encouraged to complete challenges and master chemistry concepts. Platforms like Kahoot! Quizlet, or specific gamified chemistry apps enables teachers to create interactive quizzes on topics such as periodic trends or chemical bonding, providing instant feedback and allowing students to compete with their peers.

Self-paced learning method gives students the flexibility to progress through chemistry content at their own speed, while adaptive learning platforms adjust the difficulty of material based on student performance.

Platforms like Smart Sparrow and ALEKS adapt chemistry coursework to the individual's level of understanding, offering extra practice on weak areas or advancing students who demonstrate mastery.

LITERATURE REVIEW

Research on digital pedagogy often refers to constructivist learning theories, which stress learner-centered environments where students build knowledge through interaction with content and peers. Digital platforms like Moodle, Canvas, and Google Classroom allow for flexible, collaborative, and interactive learning experiences. Methods like Blended Learning or Flipped Classrooms blend traditional teaching with digital tools, allowing for more personalized and active learning. Literature by scholars such as Garrison and Vaughan (2008) on blended learning offers insight into its effectiveness in promoting critical thinking and self-directed learning.[1] Chemistry education requires the mastery of both abstract concepts (e.g., molecular structure) and practical skills (e.g., laboratory techniques). Through simulations, visualizations, and interactive models, digital platforms can bridge the gap between abstract theory and practical application. Research by Johnstone (1991) [2] highlights how students often struggle with translating between macroscopic, submicroscopic, and symbolic representations in chemistry. The application of dual coding theory (Paivio, 1986) [3] in chemistry education through digital platforms has been found to aid in the comprehension of complex concepts by presenting both visual and verbal information. Many platforms offer virtual laboratories or simulations (e.g., PhET simulations) that provide students with hands-on experience in a controlled, risk-free environment. Studies show that virtual labs can complement physical laboratories by reinforcing students' conceptual understanding and enhancing their problem-solving skills. For instance, Smetana and Bell (2012) [4] highlight the benefits of using simulations in science education to increase engagement and comprehension. Some digital platforms use gamified learning to motivate students by incorporating elements like scoring, badges, or challenges. Literature on educational gamification (e.g., Deterding et al., 2011**)** underscores its potential to boost student engagement and retention. [5] Following Mayer's Cognitive Theory of Multimedia Learning (2009), digital platforms should be designed to use multimedia tools (videos, animations, interactive elements) effectively to optimize chemistry teaching. This includes using segmenting (breaking down information), modality (visual and auditory information), and contiguity (placing related information close together). [6] Digital platforms offer diverse tools for both formative (ongoing) and summative (final) assessments, which are critical in monitoring student progress in chemistry. Research on feedback mechanisms (Hattie & Timperley, 2007) indicates that timely, specific feedback, often facilitated by digital tools, enhances learning outcomes. [7] Literature on self-regulated learning emphasizes how digital platforms empower students to monitor their progress through quizzes, interactive exercises, and reflection tools. Zimmerman (2002) [8] points out that these platforms help students develop metacognitive skills essential for mastering complex subjects like chemistry. Numerous studies have examined the effectiveness of digital platforms in enhancing chemistry learning outcomes. For example, research by Chiu and Linn (2014) demonstrated how computer-based molecular visualization tools improved students' understanding of chemical reactions. [9]

In Uzbekistan, research works on "Use of digital technologies in the effective organization of the activities of educational institutions" were conducted by Saidova Kh.R. and Tursunbekova M.Sh. According to them, "Each learner has a unique learning style and pace. Digital platforms take these differences into account and provide an individualized approach to each learner." [10] So, S. Karimov studied the concept of digital competence of the teacher in his research and reforms related to the digitization of ethe education. He noted in his research, "Digital platforms provide a variety of resources, including video lessons, interactive labs, and quizzes. These resources allow students to learn more about chemistry."[11]

RESULTS AND DISCUSSION

As a result, digital platforms allow interactive simulations and visualizations that make abstract chemistry concepts more tangible. For example, molecular models or reaction simulations help students visualize atomic structures, reactions, and the periodic table in dynamic ways. Through adaptive algorithms, digital platforms can adjust the difficulty of problems and tasks to match the learner's proficiency level. This personalization ensures that students can progress at their own pace, enhancing their learning outcomes. Constructivist learning theory emphasizes the importance of active engagement and constructing knowledge through interaction. Digital platforms encourage this by allowing students to explore virtual labs, manipulate variables, and observe chemical reactions, promoting deeper understanding. By organizing information in manageable chunks and using visual aids, digital platforms reduce cognitive overload, helping students grasp complex topics like stoichiometry or thermodynamics more efficiently. While digital platforms offer promising advancements, some challenges persist. They are the following:

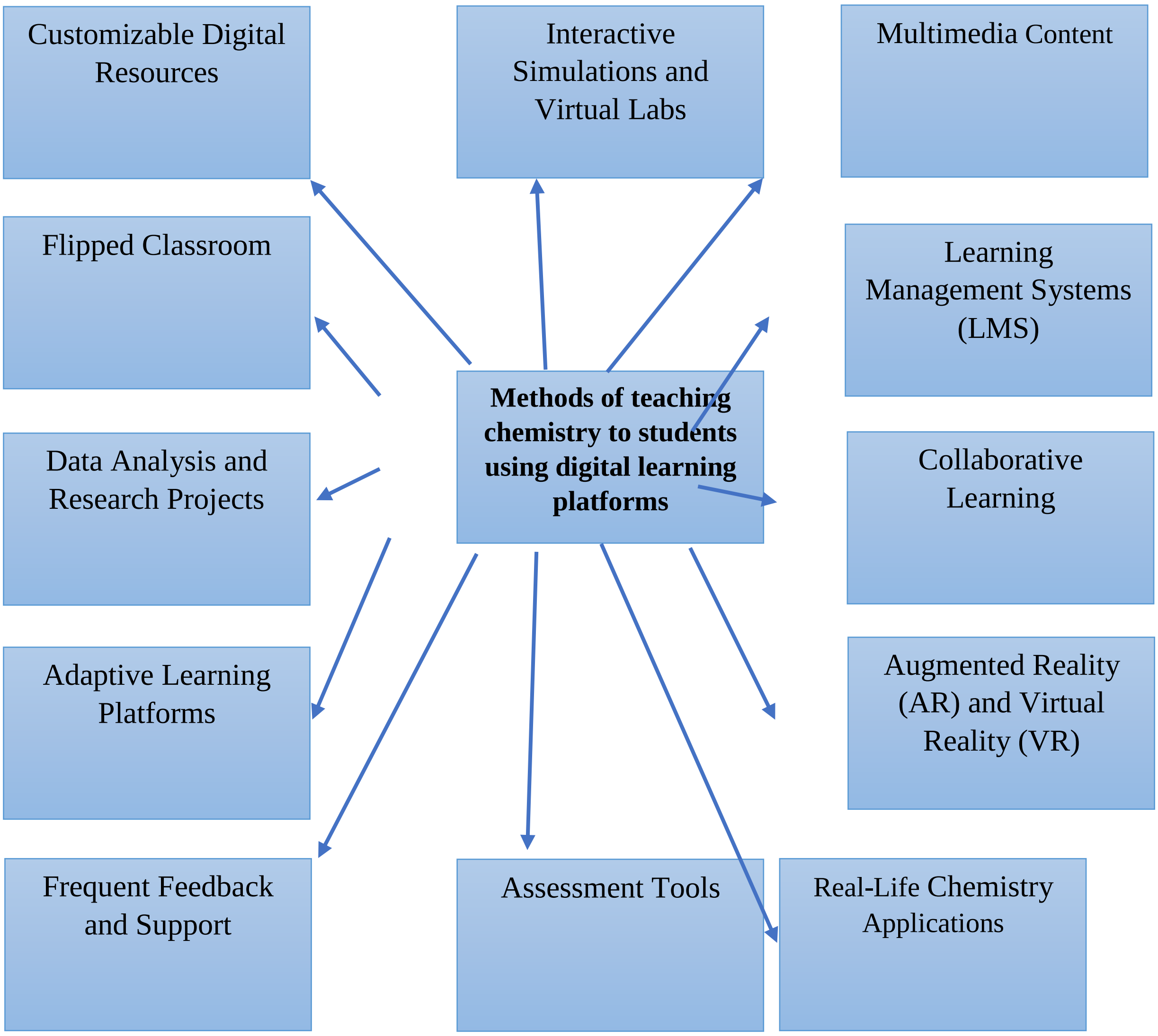
Digital Divide: Not all students have equal access to technology or reliable internet connections. This can create disparities in learning experiences, particularly in under-resourced regions.

Hands-on Experience: Chemistry, being an experimental science, requires practical lab experience. Although virtual labs provide a substitute, they may not fully replicate the hands-on learning that occurs in a physical lab setting.

Student Motivation: While gamified elements and interactive tools can boost engagement, digital platforms may also lead to distractions. Furthermore, self-paced learning demands a high degree of intrinsic motivation, which may not be present in all students.

Journal of Advanced Scientific Research (ISSN: 0976-9595)
Vol.5. Issue 10 page 133
Impact factor 9

Despite the rise of digital platforms, the role of the teacher remains crucial. Teachers guide the use of digital tools and ensure that students are not simply passive consumers of information. Blended learning models, where teachers integrate digital resources with traditional teaching methods, are most effective. Teachers help bridge the gap between theory and practice, offering support and clarification when digital platforms fall short. Teaching chemistry subjects by using digital educational platforms will be highly effective if the instruction is interactive, engaging, and aligned with students' learning needs. Below we have covered various methods of teaching chemistry to students based on digital learning platforms. (2-picture.)



Picture 2. Methods of teaching chemistry to students using digital learning platforms.

They indicate the followings:

Interactive Simulations and Virtual Labs: Engaging students with digital simulations and virtual experiments to visualize and explore chemical processes safely and conveniently.

Multimedia Content: Using videos, animations, and interactive quizzes to reinforce key concepts and create an engaging learning environment.

Learning Management Systems (LMS): Organizing content into modules, assigning tasks, tracking progress, and conducting assessments through platforms like Moodle, Google Classroom, or Canvas.

Collaborative Learning: Facilitating discussions, peer review, and group work through online forums and shared platforms to promote engagement and teamwork.

Augmented Reality (AR) and Virtual Reality (VR): Offering immersive experiences to help students visualize molecules, elements, and chemical structures in 3D.

Customizable Digital Resources: Using digital flashcards, eBooks, and apps that allow students to review and practice chemistry concepts on their terms.

Flipped Classroom: Having students learn content at home via digital tools, then using class time for application and deeper understanding through problem-solving and discussions.

Data Analysis and Research Projects: Encouraging students to conduct research using digital tools for data modeling, chemical analysis, and simulations, applying real-world chemistry.

Adaptive Learning Platforms: Using adaptive platforms to personalize learning, adjusting the pace and content based on each student's comprehension.

Frequent Feedback and Support: Providing timely feedback through automated quizzes and online tutoring to help students track their progress and correct misunderstandings.

Assessment Tools: Leveraging digital quizzes, project submissions, and online tests to assess students' understanding and encourage active learning.

Real-Life Chemistry Applications: Applying chemistry to real-world problems and case studies using digital tools for deeper exploration of industry practices, environmental science, and technology.

By combining these methods, educators can create a comprehensive, interactive, and engaging chemistry learning experience through digital platforms.

CONCLUSION

Digital educational platforms offer interactive and dynamic learning experiences that help better understand complex chemistry concepts. Visualizations, simulations, and digital tools can facilitate active learning, which improves students' conceptual understanding and application of knowledge. These platforms allow for personalized learning experiences, enabling students to learn independently. This flexibility helps to cater to diverse learning needs and styles, thus promoting independent learning skills. Teaching chemistry via digital platforms supports the development of critical thinking, problem-solving, and digital literacy skills, which are essential for students in the modern, technology-driven world. The conclusion may also highlight the evolving role of digital platforms in the future of chemistry education. Continued research and innovation are essential to optimize the use of these platforms and ensure that they align with educational goals, curricula, and learning outcomes.

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