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BYTE-SIZE CHEMISTRY OF THE FUTURE LEARNING IN HIGHER EDUCATION SETTINGS

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Abstract. Learners learn best through active involvement with concrete experiences, significantly improving academic performance. The micro-learning approach improves knowledge acquisition and information retention by making learning more engaging and motivating. Digesting and retaining smaller pieces of chemistry subject matter is easier when it is relevant to the specific learning objectives and context. This paper presents perspectives on microlearning landscapes and content creation aspects with a couple of demonstrated examples in the chemical bonding chapter and microscale chemistry practical work. These microlearning modules encourage exploring alternate solutions proceeding well beyond the single byte.

Keywords: Microlearning module; Byte sized meal; Mental registration; Active involvement

Introduction

Microlearning is the concept of breaking down targeted complex scientific information into small, easily digestible chunks. It is more accessible, engaging, and tailored to individual needs, maximizing knowledge retention. It could be personalized based on the learning pace and prior knowledge. Gamification of modules and the use of augmented reality (AR) and virtual reality (VR) to create interactive sessions can increase engagement and information retention, considering the current attention span and motivation levels of young learners (Alias, & Razak, 2023; Kohler et al., 2021; Salas-Díaz & González-Bello, 2023; Taylor & Hung, 2022). Short explainer videos on a mobile app, small multimedia presentations, interactive micro-quizzes, and AR/VR-based learning experiences coupled with flexibility and accessibility can better capture learner attention and cater to individual learning progress and needs. Just-in-time learning approach allows learners to access the desired information conveniently. Teaching chemistry in a macro-learning conventional method could just lead to confusion on chemical concepts/ideas/principles/applications. Rational decisions about chemistry-related issues can be taken depending on learners' grasp of science and scientific spirit.

Expert scientific opinions based on credentials such as training or experience matter while credible information with facts and a vast front of chemical knowledge provide authentic chemical perspectives involving conceptual and analytical reasoning.

The potential of bite-sized learning approach in music/medical/adult/online education, and psychiatry and its effectiveness on student learning outcomes indicates that micro-learning is a practical solution in the higher education landscape because of four key characteristics: i) short, focused modules, often focusing on a single concept or skill ii) accessibility and flexibility, anywhere, anytime, allowing them to learn at their convenient time, iii) content designed to address specific performance needs or practical applications, and iv) learner-centric approach using interactive formats enhances engagement (Mazlan et al., 2023; Manning et al., 2021; Ho et al., 2023; Schwartz et al., 2019). This paper presents the importance of integrating micro-learning modules into the chemistry graduate student education space and the pathways associated with an innovative learning experience. It summarizes the existing studies in this area and suggests future directions that are critical to the role of emerging trends in chemistry. This microlearning content can reach billions, unlocking productivity and improving standards of living globally through a multitude of contemporary science knowledge-enriching and skill-enhancing programs to transform visionary ideas into reality.

Methodology and Results

Combining qualitative studies, content design, analysis of bite-sized learning materials, and result analysis is the mixed-method research methodology adopted in this study involving the physical classroom setting and online learning materials. The content was experimented with the actual postgraduate chemistry classroom and the questions about the engagement and understanding of the subject were assessed by asking relevant questions and then using qualitative interactions and answers to explore the reasons for enhanced experience. The content of the chemical bonding chapter is designed according to the challenges posed by the contemporary world. The examples of research questions asked orally in the classroom include the following; i) Does the bite-sized learning leads to higher knowledge retention compared to conventional learning techniques? ii) How does the microlearning content impact learning outcomes? iii) What are the factors that contribute to learner engagement while learning in small chunks? and iv) What are the learner perceptions of bite-sized learning in the higher educational setting?

The responses received from the students were positive, suggesting that they were likely satisfied with their learning experience. They have retained a lot as reflected in their correct responses to tricky questions asked as per the random roll number scheme in the very next class. This retention is essential for skill development in a fast-paced and competitive landscape. Typical sample questions in the bonding chapter include the following; Why should atoms form chemical bonds? Why a dangerous sodium metal reacts violently with poisonous chlorine gas to form harmless table salt? How do you explain the stability of metallic bonds? Explain why CO_2 is linear while H_2O/SO_2 is bent, CH_4 is tetrahedral rather than square, C_6H_6 is arranged as a hexagon rather than a prism. Describe the energy profiles of covalent, ionic, and metallic bond formation. Depict the hybridization in ethane/ethyne. How do you distinguish bond energy from bond dissociation energy? Predict whether the ozone molecule is polar. How do you perform the simple practical tests for the polarity of the molecules? Predict the stability of sodium dichloride. What happens when an ionic solid dissolves in water? Give reason: Reaction between ionic compounds in aqueous medium is instantaneous while that between organic compounds is not. Why does non-polar sugar dissolve in polar water? Why is solid ice less dense than liquid water? Why is it possible to write on paper with graphite and not with diamond?

The above questions encourage critical thinking about bonding aspects and impacts in the real world. The microlearning concept as applied to the chemical bonding chapter was taught in postgraduate chemistry programs in the even semester. Its specific impact on student success is reflected in answering the oral questions in the next class, regular tests and end-semester examination performance. The idea of structuring bonding aspects into small steps and goal orientation has a positive impact on the student's learning. This teaching technique impacted students' success by making learning more efficient, engaging, and flexible, leading to enhanced understanding, improved knowledge retention, and better performance. The learning satisfaction is also reflected in the excellent student feedback comments received at the end of the semester. Similarly, microscale chemistry practical work was conducted in the postgraduate chemistry laboratory sessions and their impact on the learner performance was assessed in the laboratory tests and end-semester practical examinations. During classroom sessions, students are encouraged to think in analytical, logical, autonomous, and creative forms. They can later extend the rational logical analysis to solve problems related to welfare and social justice by asking appropriate questions. They can suggest alternative ways of thought and action regarding problems of the larger society in the future as today's learners in the formal category of educational institutions are tomorrow's leaders.

Bite-sized learning modules were designed and developed for the chemical bonding chapter and presented in the regular classroom. Also, a PDF version of the twelve modules on chemical bonding was uploaded to the learning management system (LMS). Probing questions were asked to several students in the next class to assess their understanding of the subject matter. The learning outcome was further evaluated by regular mid-term tests and end-semester examinations. Qualitative analysis of responses received from postgraduate students suggests that the microlearning modules have influenced their learning outcomes. These internal classroom survey questions included logical, higher-order thinking, and application-based questions. The students found it easy to answer the questions after the classroom teaching. No learning gap was detected, indicating improved learning outcomes as there is less clutter and more clarity in the learner's mind. Students of the class participated enthusiastically in a randomized experiment in which interesting questions were asked and objective assessment was maintained. It is essential to motivate learners by offering positive reinforcement and well-placed criticisms. Active involvement of students in such an exercise has resulted in mental registration of bonding concepts, principles, and applications. We have witnessed a rapid enhancement in a stable learning experience contributing to learners' academic lives. A short, focused teaching-learning interaction helped them recall information after a few days. When combined with cross-questions, they become a powerful tool for understanding. The breadth of the various bonding aspects and impacts uncovered during classroom sessions broadened their perspectives and equipped them with insights needed to thrive in today's competitive global environment.

Microlearning Landscape Matters

Bit by bit, the six Cs of excellence involving core interest, commitment, concentration, consistency, cooperation, and competence lead to learning, success, happiness, and growth. A methodical exploration of online resources and traditional textbooks can be used to develop micro-learning content on a specific subtopic through a chain of thought, comparison, and synthesis (Mostrady et al., 2025; Dolasinski, & Reynolds, 2020; Putri et al., 2024; Fialho et al., 2024). The resulting cohesive narrative must inspire a certain degree of intellectual curiosity in aspiring chemistry learners. The learner gets the opportunity to learn small chemistry chunks rather than taking it as a whole to make learning effective. A science teacher can enhance motivation for learning science through microlearning modules on interesting and trending topics. There is constant pressure to develop quality micro-content quickly in many science subjects, at low cost. The science concepts can be understood in detail and relate to the learner's previous scientific knowledge. It does not put much pressure on faculty members, enhances their ability to focus, and less disruptive, and easier to fit into the normal working day. This teaching approach involves students in active learning mode that emphasizes questioning, data analysis, and critical thinking and includes hands-on training activities/laboratory experimentation where teachers serve as facilitators.

The five E learning cycle model for science teaching involving engaging, explaining, exploring, elaborating, and evaluating while connecting prior knowledge with new concepts could be incorporated into the microlearning module (Javorcik, et al., 2023; Tian et al., 2023). Development and implementation of microlearning content to improve motivation and learning outcomes of students includes expertly curated content where they are meticulously edited by professional chemists to ensure articles are understandable and useful to educators and adopt innovative teaching approaches/high-impact teaching methods for classroom instruction. Higher education institutions and universities offering various undergraduate and postgraduate programs in various science fields can adapt this microteaching practice to foster a culture of academic quality. The use of chemistry microlearning instructional materials plays an integral role in teaching chemical bonding in higher education institutions. Chemical bonding is such a fundamental concept to understanding matter around us, from carnival to carnage. Finding solutions of many global issues through chemical dynamics involving bond-breaking and bond-making requires chemistry knowledge. The improved knowledge through the process of microlearning can be applied and create solutions to global scientific problems and explore the natural phenomena on the planetary surface through the chemistry lens.

Content Creation Aspects

Our teaching actions have a ripple effect on young minds in the hyperconnected world we live in. The growing importance of microlearning as a critical educational tool in making learning an engaging and stress-free experience to achieve academic excellence helps learners explore their cognitive potential. Proper content creation in each important topic in every scientific discipline can improve higher education quality and power youngsters toward innovation and research. It is essential to express the chemical bonding concepts in a manner and form easily understood by the common readers and to be applied in teaching and research. The microlearning series we have designed aims to present young readers with an increased understanding of chemical bonding through enhanced content in the reconstructed text for teaching-learning interactions, which yields a satisfactory meaning in the bonding context. Choosing unconventional or out-of-the-box approaches in content development would make a more fundamental shift in thinking and have a far-reaching impact on the international stage with global growth prospects.

It is important to optimize learning outcomes in this age of information overload and vast interdisciplinary topics in each scientific discipline. Microlearning modules aim to educate the learners about learning in bits and bytes, fostering a culture of proactive learning management. This learner-focused approach catalyzes transformative educational changes in the higher education system. The subject matter content is designed, developed, and presented to serve as a knowledge powerhouse to the human mind, delivering exceptional learning outcomes. An elevated learning experience makes learners think clearly and develop innovative ideas, enhancing overall personal and professional growth and productivity. This microlearning series involves several interconnected chemical bonding concepts, ensuring a comprehensive learning experience. The overall perspective of chemical bonding principles emphasizes delivering exceptional educational services to the learning community while maintaining the highest standards of teaching-learning interactions. Balancing current expertise with emerging trends using generative artificial intelligence technology tools will be key to staying ahead of the learning curve. We believe that microlearning is a good first step in helping youngsters understand the subject and navigate the professional world around them with global exposure and resources.

Example of Chemistry Application

In this microlearning module series, we have designed and developed 12 manuscripts in the format – Bytes and Bonds – Part 1-12, Title, Abstract, Keywords, Learning Objectives, Introductory Perspectives, Body (headings), Summary and Outlook, Review Questions (10 in each), References Cited (15 in each). These manuscripts cover various aspects of bonding, including inorganic and organic examples, and have typically 10 pages (~3000 words, 1-2 figures/tables). Microlearning lessons on chemical bonding are outlined below and sample modules are available upon request.

Outline of Chemical Bonding Theory- Microlearning Module Series

Bytes and Bonds Part – 1 to 12

1. An Overall Perspective on Concepts of Chemical Bonding
2. Evolution of Model of Bonding and Their Implications in Explaining Molecular Shapes
3. Perspectives on Energy Profiles of Chemical Bonds and Bond Energy Trends
4. Understanding the Properties of Metals, Covalent and Ionic Compounds
5. Bond Polarity, Partial Ionic Character, and Dipole Moment Applications
6. Perspectives on Bond Parameters and Molecular Stability Aspects
7. Structures of Covalent, Ionic, and Metallic Substances
8. Perspectives on Theories to Explain Primary Chemical Bonding
9. Significance of Secondary Bonding Forces in Chemistry
10. Selected Specific Bonding Interactions in Chemistry
11. Strained Molecules, Electron Transfer, Free Radicals, and Isomerism
12. Chemical Bonding Aspects and Impacts on Daily Life

Microscale Chemistry Practical Work

Conventional laboratory-scale methods could just lead to confusion on chemical concepts/ideas/principles. A small-scale approach to practical work reaps big impacts on maximizing learning, and creating a memorable experience while too much content squeezed in can create confusion in the minds of learners, especially in the higher education ecosystem. Interdisciplinary learning frameworks involving intellectual rigor, academic innovation, and technically fortified microlearning content provide a transformative learning experience for students in today's interconnected, digital age. The meticulously designed programs combining classroom learning with real-world laboratory sessions, rooted in the values of the 3Ds of discipline, dedication, and determination can find a career path to success. Promoting microlearning activities will make the student community healthier and more empowered to spark their imagination and curiosity on multiple levels. Microscale chemistry laboratory experiments were performed by the students in their weekly laboratory sessions and their learning was assessed during laboratory examinations.

The benefits of microscale chemistry experiments include enhanced safety due to smaller amounts of chemicals, faster experiment times, lower costs, reduced waste, and better suitability for individual performance. However, there are challenges with precise measurements, specialized equipment requirements, and potential difficulty in observing changes during some reactions due to small-scale operations. Improved safety is because of minimal chemical amounts that reduce the risk of accidents, spills, and inhalation of toxic vapors. Less chemical waste generation is due to microscale, contributing to environmental sustainability. Reduced costs for reagents and disposal, quicker reaction times, and individualized learning are other benefits of microscale chemistry. Learners must develop a keen sense of observation when working on small quantities and microscale experiments is suitable for diverse settings. However, precision challenges, specialized equipment, observation difficulties, and additional training must be a part of an elaborate effort to achieve goals.

Typical examples of demonstrations of microscale chemistry experiments include the following using small quantities of reagents. i) Investigating the pH of different solutions using a universal indicator is quick and safe, by adding drops of acid, base, and neutral solutions to the indicator. It is easy to understand the concept of pH and how it changes with different solutions. ii) Identification of aldehydes and ketones using 2,4-dinitrophenylhydrazine reagent, by adding it to different solutions containing aldehydes and ketones and observing the formation of yellow/orange precipitate. Students learned about functional group identification using specific reagents and the microscale advantage is that the experiment is safe, quick, and easy to implement. iii) Similarly, by dropping different metal (Cu, Mg, Zn, & Fe) salt solutions onto the respective metals and observing the reaction to determine the order of reactivity of metals, the learners understand displacement reactions. They can write equations for the observed reactions. The above experiments can be completed quickly, using minimal reagents, less risk of accidents and exposure, reduced waste and lower environmental impact, lower reagent cost, simple equipment, and minimal cleanup. These benefits of microscale chemistry make it a valuable tool for both teaching and research. Such experiments were implemented as a part of the main laboratory course in the curriculum structure of the postgraduate program to inculcate the habit of performing microscale chemistry experiments. Learning by experimenting on a small scale as a part of the regular chemistry laboratory session was a bit the same for the theory classes involving more discussion. The above experimental procedures along with background information on their significance were discussed in advance in the theory classes to facilitate smooth conduction of practical.

Conclusions

Microlearning in a chemistry higher education setting offers significant benefits in having byte-sized and focused learning modules. It is a valuable tool to adapt to young learners' needs due to improved engagement, domain knowledge retention, and better learning outcomes. It offers flexible delivery, accessibility, and personalized learning experiences to learn at their own pace and cater to diverse learning styles. However, careful consideration of authentic learning material and proper implementation are crucial to maximize its effectiveness. Specific learning objectives, concise information, and relevant assessments are necessary for the content design. Interactive features, learning management systems, and training the trainers are essential to maximize its impact. Microlearning has the potential to revolutionize science education upon proper execution.

It's time people change their perception of chemistry as a difficult-to-learn subject. Spreading a correct public image of chemistry through chemical education microlearning resources reflects a deep commitment to societal contributions, with community outreach programs and multiple social initiatives that instill values of empathy, safety, and responsibility. The integration of modern technologies like artificial intelligence (AI), machine learning (ML) and tools such as generative AI supports the focus on innovation further in incorporating the latest domain knowledge. The choices made today will shape the countries' intellectual and economic landscape in the tech-driven world to become hubs of learning and development (L & D), research and development (R & D), and innovation and development (I & D) in the ever-evolving higher education landscape. A meaningful orienting experience and the transformative power of microlearning will be more effective if we balance the narrative between universality and specificity and maintain the spirit of designing impactful content with dedication and effective implementation of such bite-sized learning modules in the higher education system is recommended.

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