

Development of Animation Content on Chemical Bonding to Enhance Learning of Chemistry at Senior Secondary Schools in Bauchi, Nigeria

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Abstract

This study was carried out to address the issues of abstractions on the concept of chemical bonding in chemistry and ensured that students learn better. To address that, two research objectives were raised to guide the study: develop animation content on chemical bonding and test it on students to ascertain the impact it has on their learning outcomes. The process of developing animation content passed through three painstaking stages of production. The study used pretest-posttest design of quasi experimental research method where 140 students drawn from seven senior secondary school within Bauchi local government area were assigned to either the control group or experimental group. Both groups were pretested to ascertain their initial academic achievements. Thereafter, the experimental group received the treatment and both groups were posttested to ascertain the effect of the developed animation content on the students. The results were analysed using independent sample t-test at 0.05 level of significance. The p-values from the respective schools are GHKUC with p-value of 0.0271; GCDSSB with p-value of 0.0242; GDSSMLK with p-value of 0.0255; GDSSBD with p-value of 0.0286; GDSSB with p-value of 0.0261; GDSSBF with p-value of 0.0434 and GDSSGVB with p-value of 0.0208. Since these p-values were less than 0.05 level of significance, it was concluded that the results were significant in each of the school sampled. This means the developed animation content had positive effect on students' learning outcome. Therefore, learning via animation should be integrated into the secondary school curriculum to enhance students' assimilation and retention.

Keywords: Animation, Chemical Bonding, Educational Technology, Multimedia Learning, Visual Learning, Chemistry.

Introduction

Animation is recognised as a powerful tool for conveying information in a clear and engaging way (Finlay, 2025). It holds the key of transforming educational sector and developing the way people learn in the modern society. Animation incorporates various educational tools that merge auditory and visual elements together to enhance learning experience. These elements play a vital role in delivering information, concepts, and ideas dynamically and attractively (Ashikuzzaman, 2023). This approach appeals to different learning preferences, aiding better comprehension and retention of information.

Animation content integrates audio-visual elements as drivers in the delivery of learning objective. Because, audio-visual materials engage both the auditory and the visual senses simultaneously - thereby facilitating multisensory learning (Ashikuzzaman, 2023). Animation has been shown to be more effective than static graphics in helping learners build mental models of processes involving changes over time (Hoffler & leutner, 2007 as cited in Amarin, 2016). Visual simulation of how electrons of one atom react with the electrons of another atom helps learners build mental model of the processes thereby enhance assimilation and retention. It is imperative to note that, abstract concepts often pose a challenge to students. But animation or audio-visual materials provide a solution by breaking down intricate ideas into digestible segments for better understanding by students.

Although verbal presentation offers a powerful tool for humans, however, an alternative to purely verbal presentations is the use of animation content in which people learn from both voice and simulated images. It provides instruction regarding abstract phenomena (Urquiza-Fuentes & Vel'azquez-Iturbide, 2009 as cited in Aysolmaz & Reijers, 2021). Because, abstract concepts further pose a challenge and add to the cognitive load of the learners. But visual erodes abstraction and enables the learners to comprehend effectively the concept being portrayed or demonstrated and retain same. This avowal has given credence to the potentiality of visualisation as a powerful tool that opens new horizon of learning experience.

Chemical bonding has been considered to be one of the difficult concepts in chemistry for students especially at secondary school level (Azeez, et al, 2017 as cited in Olubunmi, 2023). The difficulty been faced by the learners is as the result of misconception or misunderstanding due to abstract chemical concepts (Olubunmi, 2023). The misconceptions that students hold of individual bonding models are on different kinds of chemical bonds (Hunter, Rodriguez & Becker, 2022)

Müller, Reiher, and Kapur, (2024) alluded the root cause of misconceptions or misunderstandings to either oversimplification or overgeneralisation. For example, students often oversimplify ionic compounds by assuming that ionic bonds only exist between alkali metals and halogen atoms (Özmen, 2004 as cited in Müller, Reiher & Kapur, 2024). Assumption issue is raised because of the abstract nature of chemical bonding; hence the development of animation content; because, abstract concepts can be demystified through the application of animation. Animation advances the understanding and engages the focus of the student by providing explicit information through non-textual, attention-grabbing gestures, tone of the content, sound and background music in an enjoyable learning environment which generates learning engagement for a longer time and offers motivation (Ünal Çolak & Ozan, 2012 as cited in Rashid, Khanum & Khan, 2024). Students often learn more when they appreciate what they are doing; utilizing simulation as a device makes them feel that learning is fun as well as entertaining. This enables them to create aptitudes capability in concentration, cognition and observation.

From the stand point of the cognitive theory of multimedia learning and cognitive load theory; it is recognisable that animation has great potential for improving learning during the education of students because it involves different mechanisms for utilizing the human working memory and engaging users in the cognitive process with respect to static instructions (Mayer & Moreno, 2002 as cited in Aysolmaz & Reijers, 2021). Cognitive theory of multimedia learning presents the idea that the brain does not interpret a multimedia presentation of words, pictures, and auditory information in a mutually exclusive fashion; rather, these elements are selected and organised dynamically to produce logical mental constructs (Mayer, 2001). Furthermore, Mayer underscores the importance of learning (based upon the testing of content and demonstrating the successful transfer of knowledge) when new information is integrated with prior knowledge.

Chemical bonding is one of the most fundamentals of chemistry (Azeez, et al., 2017 as cited in Olubunmi, 2023) that explains other concepts such as molecules and reactions. Without it, scientists would not be able to explain why atoms are attracted to each other or how products are formed after chemical reaction has taken place (Libretexts, 2023). But unfortunately, this aspect of chemistry is abstract which makes it difficult for student to assimilate. The assimilation of concept of chemical bonding, requires also that one first know the basis behind atomic structure. A common atom contains a nucleus composed of protons and neutrons with electrons in certain energy level revolving around the nucleus (Libretext, 2023). Knowing the basis of atomic structure requires visual representation of the simulation of such structure to break down intricate ideas into digestible segments for better understanding by students. Hence, it becomes expedient to deploy animation techniques as it has been shown that animation is suitable for presenting procedural knowledge rather than declarative knowledge that involves facts (B'etrancourt, & Tversky, 2000 as cited in Aysolmaz & Reijers, 2021).

Chemical bonding is considered difficult to grasp especially for beginners as it involves abstract ideas about electron sharing and interaction between atoms. It requires visualisation of subatomic particles which can be challenging to understand without recourse to visual simulation of the processes involved. That is why the application of animation is germane as it clarifies relationships through visual means, and changes both the instructional strategies and the teaching and learning environment (Vonganusith & Pagram, 2008). This helps in addressing visualisation needs of the learners on those subatomic particles which can be challenging to understand if not accompanied with visual simulation; because, with today's high educational demands, the conventional method of teaching has been proven inadequate in addressing the developmental requirements of the learners (Hu, 2024). Therefore, it is expedient to enhance classroom instructional techniques by embracing animation, because it offers exciting possibilities in meeting the needs of 21st century learner.

Chemistry is one of the science subjects being offered at senior secondary schools across Nigeria. But the understanding of this subject has always been a challenge to many students. Research has shown that many students do not correctly understand the

fundamental concepts of chemistry (Kamisah and Nur, 2013). Further examinations of studies revealed that chemistry is a difficult subject for students, because of the abstract nature of many chemical concepts (Chen et al., 2015). This finding was affirmed by Sanjiwani, Muderawan and Sudiana, (2020) as they assert that most concepts in chemistry are abstract and complex, so it requires a deep understanding to learn. Also, Khandagale and Shinde, (2021) lent credence to this assertion when they affirm that chemistry is a very important branch of science, yet it is viewed as a difficult subject by the learners due to misconception occasioned by abstract concepts involve. This is because most of the concepts in chemistry cannot be experienced, especially at secondary school level. Therefore, it is expedient to sufficiently motivate the students to learn chemistry by developing animation contents to aid their thinking and assimilation process for better understanding of the subject.

Consequently, the objectives are raised to guide the study:

1. To develop animation content on chemical bonding and improve learning of chemistry
2. To test the developed animation content on students to ascertain the impact it has on their learning outcomes

Methodology

The study used pretest-posttest design of quasi experimental research method, where One hundred and forty (140) students were drawn from seven senior secondary schools (SSS II) within Bauchi local government area. The subjects were assigned to either the control group or the experimental group. Both groups were pretested to ascertain their initial academic achievements. Thereafter, the experimental group received the treatment and both groups were posttested to ascertain the effect of the developed animation content on the students.

The study took place in Bauchi Local government area of Bauchi State. The study used purposive sampling technique to sample only those that were of interest to the study. The instrument the study used for data collection was multiple-choice test. The instrument used was validated by educationists; this helped in establishing the content and face validity of the instrument. The test was piloted to verify the readability of the questions. Furthermore, the reliability of the study was statistically determined using Cronbach's Alpha to determine the internal consistency of the instrument. The value of Cronbach's Alpha was found to be 0.81 on ten items. Since the value of the Cronbach's Alpha is greater than 0.70, it was considered valid (Nunnally and Bernstein, 1994).

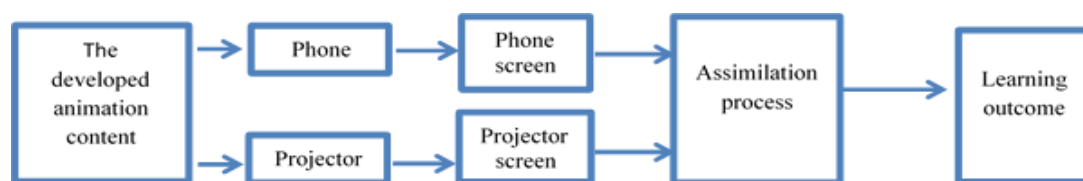


Figure 1: Model of classroom application of animation content

Result

Objective 1: To develop animation content on chemical bonding and improve learning of chemistry

Processes of Developing Animation Content on Chemical Bonding

The development of animation content on chemical bonding passed through three painstaking related stages of productions: pre-production, production and post-production. Each of the production stage contained a number of subsidiary processes that were followed to achieve the production set goal. The software used for the development of animation content was blender 4.1Apha application for window.

Pre-production

- Project planning: here, the researcher/designer laid out a strategy to ensure everything matches with the vision before undertaking a successful production. It helps manages time and budget, and improve team organization.
- Idea generation: here, the designer undertook a creative process of crafting, developing, and communicating different abstract thoughts and concepts through sketches.
- Concept creation: here, the designer developed ideas and improved upon it until the whole story was shaped. This is a basic form of what the envisioned animation would be like, including the characters, style, colour and many more.
- Script: here, the designer produced a written version of the project, containing information on the story, environments, dialogue, and even sound effects.
- Storyboard: here, the designer turned story script into a visual outline of what the eventual animation would be.
- Character creation: here, the designer creates characters and decide how these characters would interact with the environment. Also, included in this step were props, colour pallets and backgrounds.
- Voice Recording: here, the designer produced a voice record which was used at the post-production stage as the voiceover for the animation.

Production

- 3D Modeling: here, the designer created and developed a 3D geometric surface representation of object in a specialized 3D software eg, Blender.

- 3D Layout: here, the designer positioned the 3D attributes such as the characters' size, shape, and environment and built each scene as required.
- 3D Texturing: here, the designer created and applied textures (colors and surface properties) to a 3D model. At default, 3D models are usually shaded flat color.
- 3D Rigging: here, the animator/designer put a bone structure into the 3D object so as to move different parts of the geometric object as quickly and efficiently as possible.
- 3D Animation: here, the animator/designer created movements and gives the characters the feel of motion. This type of animation generates images using computer software; in this case, Blender application was used for that purpose. Instead of creating one frame at a time, the characters were created, and a skeleton helps animate the characters.
- Lighting: here, the animator/designer created the mood of a 3D scene by implementing different lighting techniques in animation including point light, directional light, spot light, and ambient light. It took several lighting effects to illuminate a 3D scene.
- Rendering: when dealing with a 3D animation, every scene is separated and rendered into multiple layers, including objects, colours, background, foreground, shadows and highlights. Although these layers would still be united again in the post-production stage. Once the animation was perfected, along with the lighting and camera angles, the animator/designer moved on and rendered it.

Post-production

- Composition: to make a final output, the layers rendered previously were put together again in an ordered sequence to create a transition between the frames of animation. This is where the final look of animation is revealed with motion, lighting and atmospheric elements.
- 2D Visual Effects (VFX): some visual effects, such as sparks, camera shakes and many more are easily achieved in a 2D environment at the end of the project without sacrificing the quality. Here, the designer mixed these effects with other layers during the composition process.
- Colour Correction: also known as colour grading, colour correction is an adjustment to the atmospheric perspective of the animation by colouring the animation in the style and genre. here, the animator/designer ensured that the colour was accurate and consistent with the genre of the animation.
- Sound effects: here the designer added appropriate sound effects that correspond with the action such as the movement of electron from one atom to another.
- Background music: here, a soft low tone music was added to the timeline. But was done in a way that it would not overcome the voiceover of the animation.

- Voiceover: here, the voice recording that was done during the pre-production stage was added to the timeline to synchronise the visuals with the audio in the animation.
- Export: here, the editor transferred the timeline to a platform format in which the video would be played; in this case it is mp4.

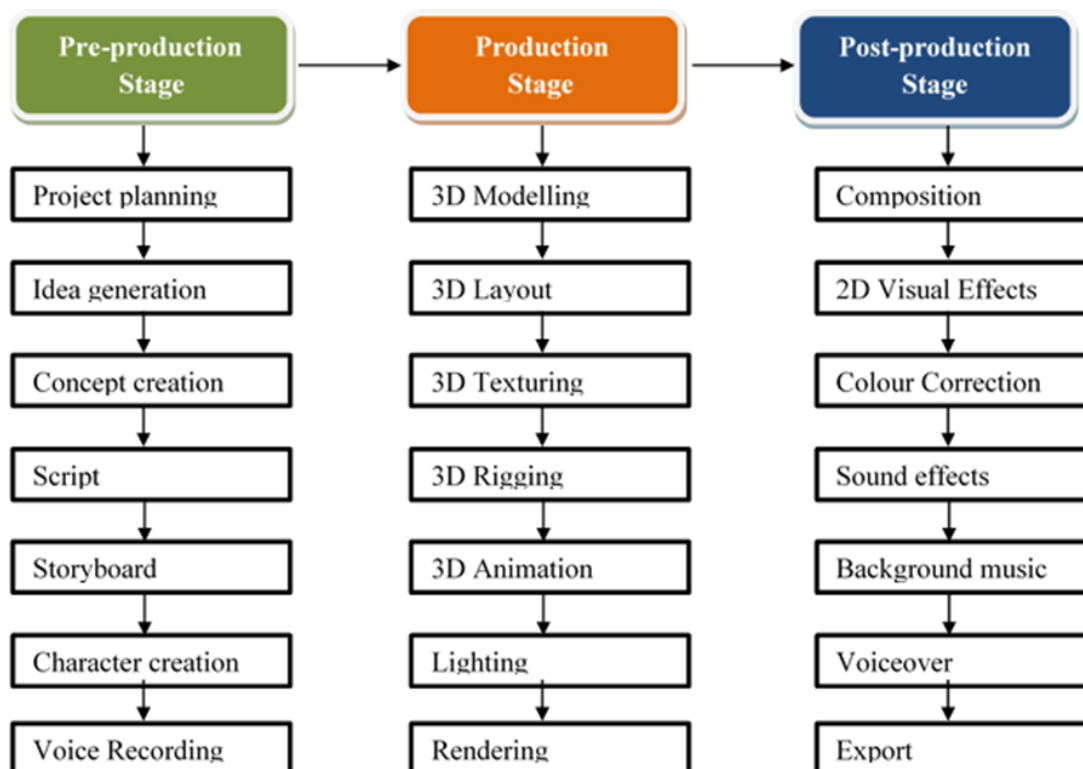


Figure 2: Flowchart of the processes of development of animation content

The flowchart in figure 2 shows the relationship between different stages of production including the subsidiary processes of developing animation content on chemical bonding. The development started at the pre-production stage and proceeded to production stage and finally ended at the post-production stage. Each of the production stages were characterised with a number of subsidiary processes that led to eventual development of animation content.

Excerpts from the developed animation content

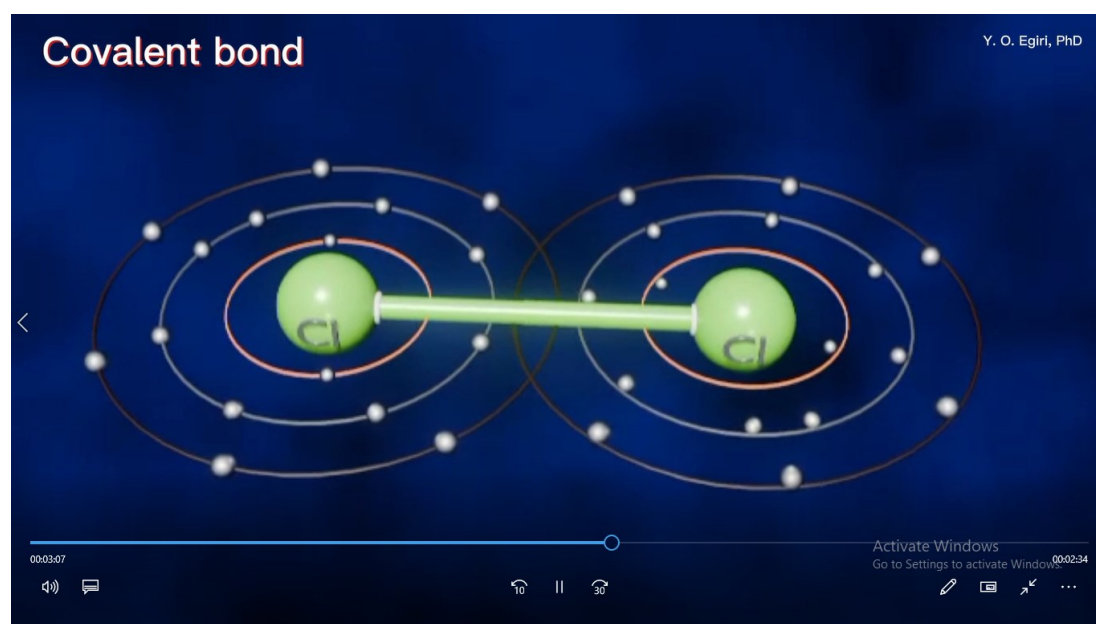


Figure 3: Illustration of electron sharing between two Chlorine atoms to form a molecule

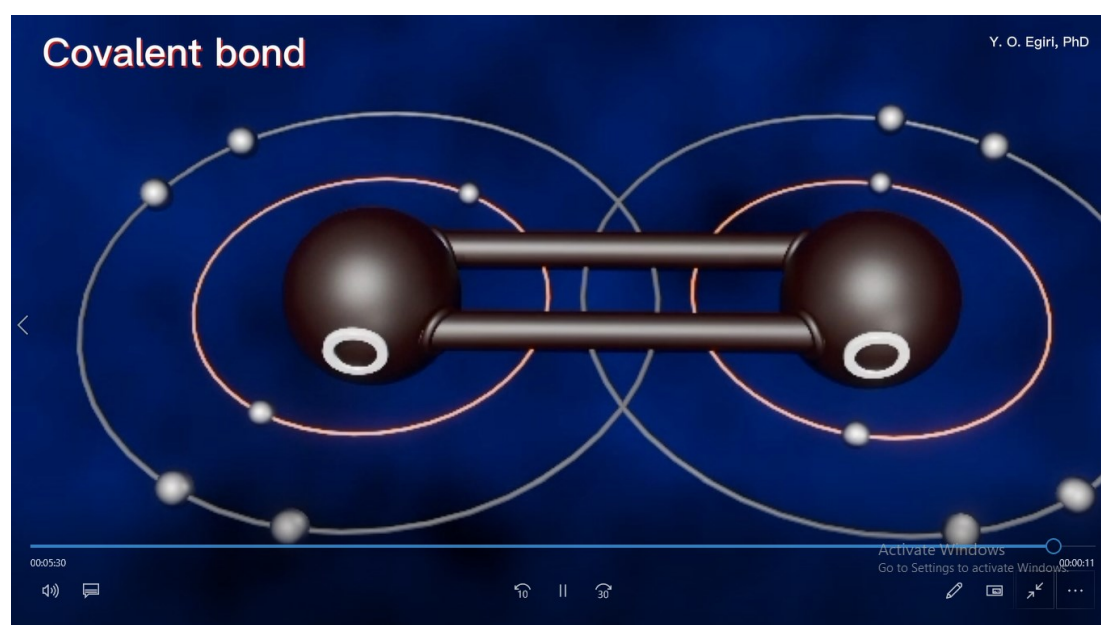


Figure 4: Illustration of electron sharing between two Oxygen atoms to form a molecule

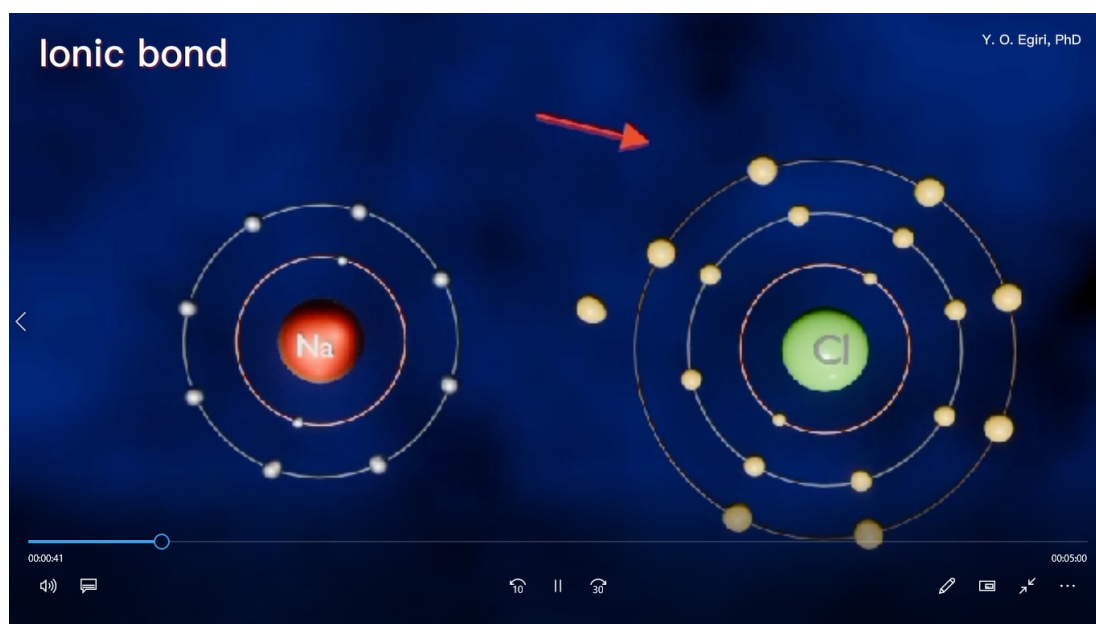


Figure 5: Simulation of the transfer of electron from sodium to chlorine

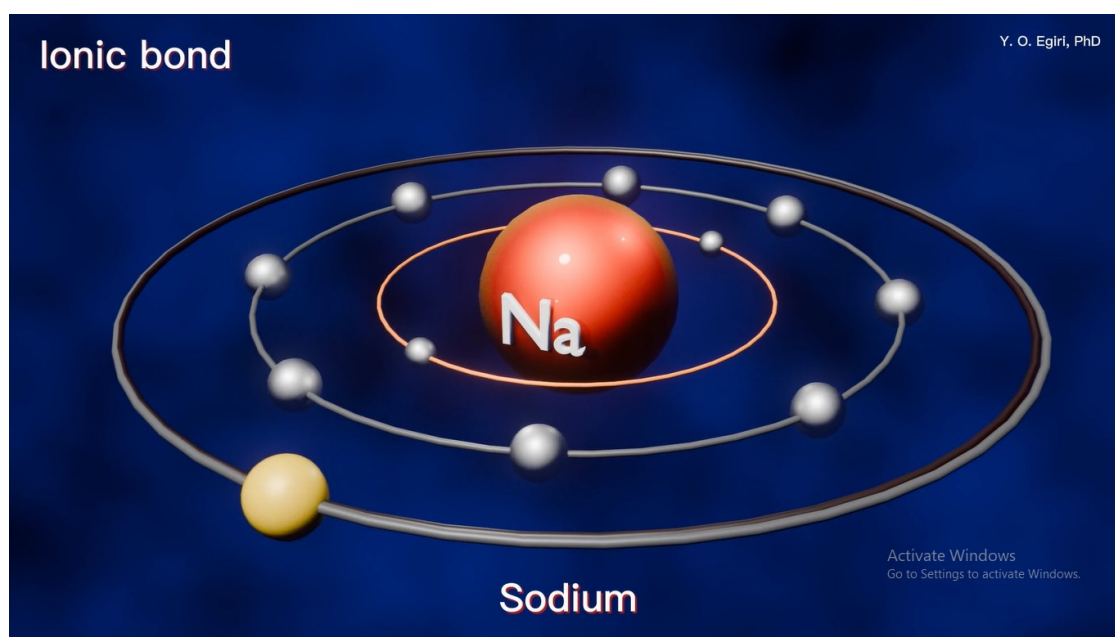


Figure 6: Identification of the number of electrons at K, L and M shells of Sodium

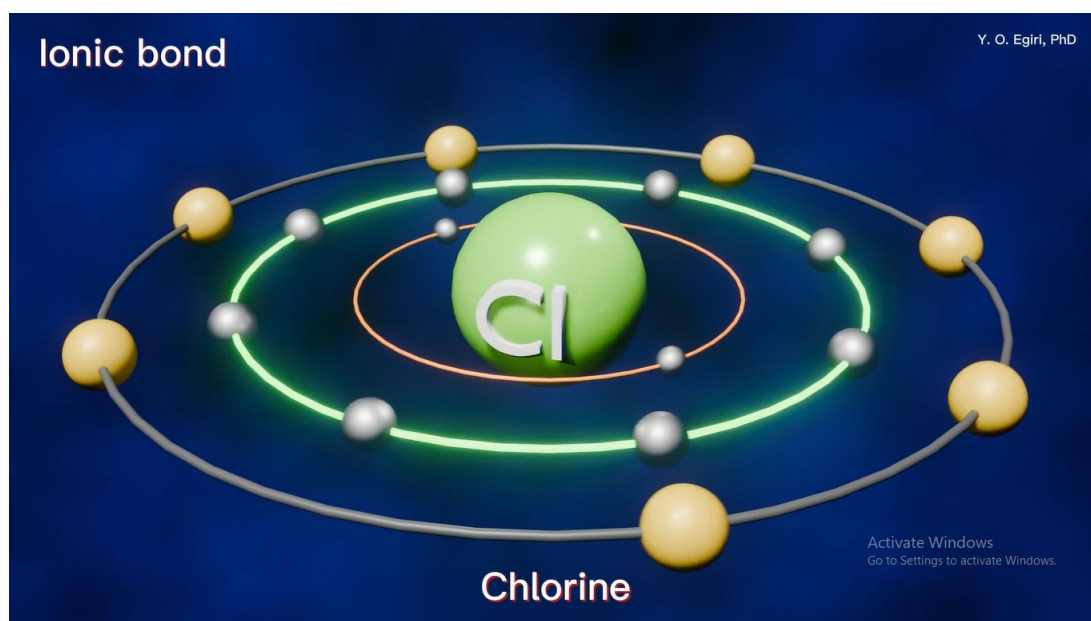


Figure 7: Identification of the number of electrons at K, L and M shells of Chlorine

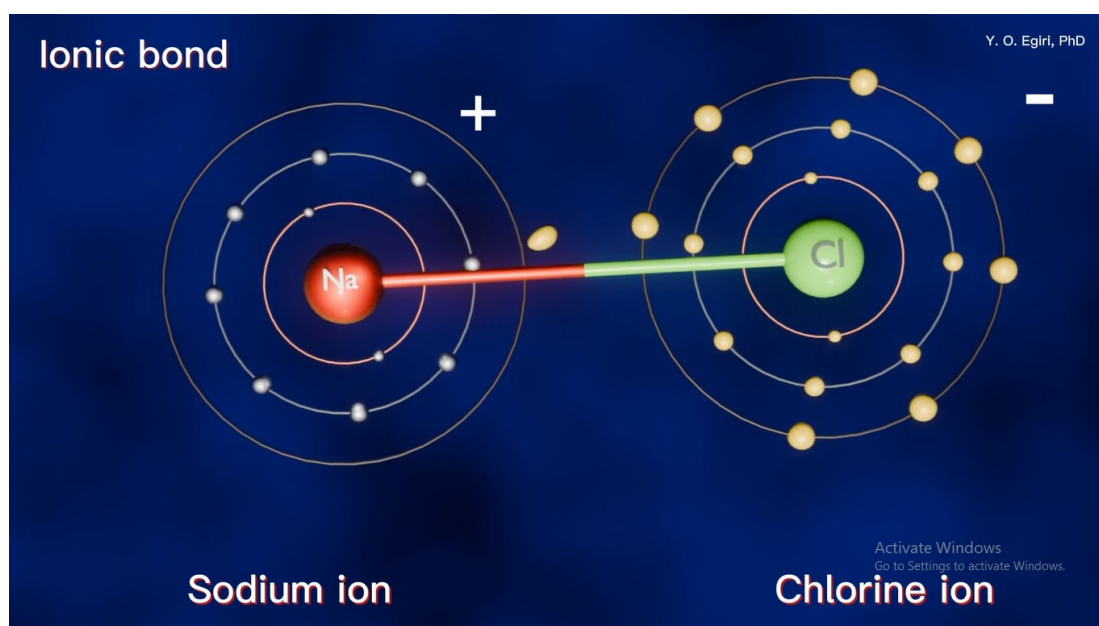


Figure 8: Illustration of Ionic bond between Sodium and Chlorine

Objective 2: To test the developed animation content on students to ascertain the impact it has on their learning outcomes

Table 1: Independent sample T-Test on the impact of the developed animation content on students' learning outcome

S/n	School	Group	N	Mean	Variance	t. Statistic	P-Value (one-tailed)
1	GHKUC	Control	10	5.5	1.6111	-2.2119	0.0271
		Experimental	10	6.4	1.3778		
2	GCDSSB	Control	10	5.3	1.3444	-2.2827	0.0242
		Experimental	10	6.4	1.8222		
3	GDSSMLK	Control	10	5.3	1.7889	-2.2500	0.0255
		Experimental	10	6.5	2.7222		
4	GDSSBD	Control	10	5.4	0.7111	-2.1807	0.0286
		Experimental	10	6.5	2.9444		
5	GDSSB	Control	10	5	2.2222	-2.2361	0.0261
		Experimental	10	6	2.8889		
6	GDSSBF	Control	10	5.1	1.2111	-1.9215	0.0434
		Experimental	10	5.9	2.1000		
7	GDSSGVB	Control	10	4.2	0.8444	-2.3753	0.0208
		Experimental	10	5.9	3.6556		

The impacts the developed animation content on chemical bonding had on students' learning outcomes were statistically determined by the application of independent sample t-test (1-tailed) at 0.05 level of significance to analyse the pre and post assessment of students' performances in the quiz that was given to them prior and post application of the learning resource. The results as shown in table 1 revealed that the p-values of the control groups and the experimental groups in each of the school where the developed animation content was applied as a learning resource were significant.

The p-value for each of the school where the learning resource (the developed animation content) was applied is less than 0.05 level of significance; which means - the application of the learning resource on students had significant positive effect on their learning outcomes. Therefore, it is crystal clear based on the results that the application of the developed animation content on chemical bonding had a huge positive impact on students' learning outcomes.

Discussion

The development of animation content on chemical bonding was done to enhance the assimilation process of students. This development passed through three painstaking related stages of productions: pre-production, production and post-production. Each of the production stage contained a number of subsidiary processes that were followed to achieve the production set goal. All the production processes were compartmented as flowchart of the processes for easy comprehension.

The developed animation content was tested to ascertain its effect on the learning outcomes of the students. The results revealed, unequivocally, the significant positive effect it had on students learning outcomes. This finding agrees with Anekwe & Opara (2021), who found learners who learned chemical bonding through animation to perform better and retained the concept, and Egbutu & Okeke (2021), who believed that computer animation and inquiry methods had a significant impact on the interest of learners in chemistry.

Furthermore, this study aligns with Omilani and Raji (2024) in their study title, 'Effect of computer animation instructional package on students' achievement in hybridization in chemistry', found that students' achievement in the hybridization concept is enhanced by the computer animation educational package. Even outside chemistry, Hanif (2020) recommended that the interactive motion graphic video material created is workable and has been shown to improve the science learning achievements of primary school children in the fifth grade based on scientific principles of independence and student learning results. In a related study, Simanjuntak, Sihite and Suyanti, (2023) suggested that the use of blended learning with Edmodo support has a major impact.

In the same vein, virtual simulations have a sizable and beneficial impact on students' physics performance (Antonio & Castro 2023), and Nsima et al. (2023) provide evidence of the significant influence computer animation techniques have on students' academic achievement in foundational science and technology courses. Also, Anggroaeni et al. (2022) in their study title 'the effectiveness of the EIGER learning strategy in promoting students' conceptual and algorithmic understanding of stoichiometry', the EIGER learning technique had a higher influence on students' conceptual and algorithmic grasp of stoichiometry. Therefore, improving students' achievement made the instructional package a valuable and effective learning tool.

Conclusion

It has been established based on the painstaking researches that have been carried out previously that chemistry has been perceived difficult due to abstract nature of chemical concepts. This necessitated the development of animation content on chemical concept to enhance learning of chemistry at senior secondary school level. The animation content was eventually developed and applied to ascertain if it could erode abstraction and enable the students to assimilate this abstract concept in chemistry better. The result of the study revealed huge positive effect on students' academic achievements. This has given further

credence to the potentially of animation to eradicating misconception occasioned by abstract concepts in chemistry. Because, it opens a new horizon of learning experience where students learn extensively via animation content thereby enhanced their assimilation process for optimum performance in chemistry.

Therefore, it is expedient to used animation increasingly frequently in schools to depict dynamic changes and illustrates abstract concepts that might be otherwise difficult to comprehend. Because animation clarifies relationships through visual means, and changes both the instructional strategies and the teaching and learning environment that encourage multisensory learning.

Recommendations

- Learning via animation content should be integrated into the secondary school curriculum to enhance students' assimilation process.
- Teachers should be trained on the use of animation content during classroom delivery to enhance students' assimilation and retention.

References

- Anekwe, C.E & Opara, M.F. (2021). Effect of Animation as Instructional Strategy on Students' Achievement and Retention in Chemical Bonding. *International Journal of Research in Education and Sustainable Development*, 1(8), 2782-7666.www.ljaar.org
- Anggraeni, N.F., Rahayu, S., Fajaroh, F., & Effendy, E. (2022). The effectiveness of the EIGER learning strategy in promoting students' conceptual and algorithmic understanding of stoichiometry. *International Journal of Instruction*, 15(4), 35-56. <https://doi.org/10.29333/iji.2022.1543a>
- Antonio, R.P., & Castro, R.R. (2023). Effectiveness of virtual simulation in improving secondary students' achievement in physics. A meta-analysis. *International Journal of Instruction*, 16(2), 533-556.<https://doi.org/10.29333/iji.2023.16229a>.
- Ashikuzzaman M. D. (2023) Visualizing Knowledge: The Impact of Audio-Visual Materials on Educational Excellence. LIS Education Network.
- Aysolmaz, B., & Reijer, H. A. (2021) Animation as a dynamic visualization technique for improving process model comprehension. *Journal of information & comprehension*; 1-19 doi.org/10.1016/j.im.2021.103478.
- Chen, S.-C., Hsiao, M.-S., & She, H.-C. (2015). The effects of static versus dynamic 3D representations on 10th grade students' atomic orbital mental model construction: Evidence from eye movement behaviors. *Computers in Human Behavior*, 53, 169-180. <http://dx.doi.org/10.1016/j.chb.2015.07.003>
- Egbutu, R.N., & Okeke, S.O.C. (2021). Effect of computer animation and inquiry method on chemistry students' critical thinking and achievement. *Journal of Research & Method in Education (IOSR-JRME)*, 11(2), 42-48.www.iosrjournals.org.
- Finlay, J. (2025) unlocking the power of Animation; How animation helps in Education. Retrieved on 5th of February, 2025 from <https://www.mythstudio.co.uk/articles/how-animation-helps-in-education>
- Hanif, M. (2020). The Development and Effectiveness of Motion Graphic Animation Videos to improve primary school students' sciences learning outcomes. *International Journal of Instruction*. 13(4), 247-266.<https://doi.org/10.29333/iji.2020.13416a>

- Hu, J. (2024) The Challenge of Traditional Teaching Approach: A Study on the Path to Improve Classroom Teaching Effectiveness Based on Secondary School Students' Psychology. *Proceedings of the 2nd International Conference on Social Psychology and Humanity Studies*. DOI: 10.54254/2753-7048/50/20240945
- Hunter, K. H., Rodriguez, J.-M. G. and Becker, N. M. (2022) A Review of Research on the Teaching and Learning of Chemical Bonding. *J. Chem. Educ.* 99 (7), 2451–2464.
- Kamisah, O. & Nur, S. S. (2013) Conceptual Understanding in Secondary School Chemistry: A Discussion of the Difficulties Experienced by Students. *American Journal of Applied Sciences*, 10(5), 433-441. <https://doi.org/10.3844/ajassp.2013.433.441>
- Khandagale, V. S. & Shinde, A. V. (2021) Investigation of Misconceptions for Valency and Chemical Bonding among High School Students. *International Journal of Innovative Research in Technology*. (8)3 pp 539-544
- Libretexts, (2023). Introduction to chemical bonding. Retrieved on 12th of February, 2025 from [https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_and_Websites_\(Inorganic_Chemistry\)/Chemical_Compounds/Introduction_to_Chemical_Bonding](https://chem.libretexts.org/Bookshelves/Inorganic_Chemistry/Supplemental_Modules_and_Websites_(Inorganic_Chemistry)/Chemical_Compounds/Introduction_to_Chemical_Bonding)
- Mayer, R. E. (2001). *Multimedia Learning*. NY, Cambridge University Press.
- Müller, C. H., Reiher, M. and Kapur, M. (2024) The Multiple Student Conceptions of the Chemical Bond in a Quantum Chemical Context. *J. Chem. Educ.* 101, 3039–3049
- Nunnally, J. C. & Bernstein, I. H. (1994) the Assessment of Reliability. *Psychometric theory*. 3, pp 248-292
- Khandagale, V. S. & Shinde, A. V. (2021) Investigation of Misconceptions for Valency and Chemical Bonding among High School Students. *International Journal of Innovative Research in Technology*. (8)3 pp 539-544
- Olubunmi, O. P. (2023) Identification of Difficult Topics in Chemistry Curriculum as Perceived by Secondary School Students in Ado Ekiti. *Journal of Research in Science Education (JORISE)*. 4 (1) pp 9-17
- Amarin, N. Z. (2016) Beyond segmented instructional animation and its role in enrichment of education and technology. *International Journal of Computer Graphics & Animation (IJCGA)* (6)3, pp 17-33 DOI: 10.5121/ijcga.2016.6302
- Omilani, N. A., & Raji, S. A. (2024) Effect of computer animation instructional package on students' achievement in hybridization in chemistry. *International Journal of Instruction*, 17(3), 435-452. <https://doi.org/10.29333/iji.2024.17324a>
- Rashid, N., Khanum, N. and Khan, F. R. (2024) the effect of Animation as a Teaching tool on Students' Learning – an Experimental Study. *Media Literacy and Academic Research* 7 (1) pp 129-144
- Sanjiwani, N. L. I. Muderawan, I. W. & Sudiana, I. K. (2020). Analysis of Student Chemistry Learning Difficulties on Buffer Solution at SMA Negeri 2 Banjar Buleleng Bali. *Journal of Physics: Conference Series* 1503 p. 012038
- Simanjuntak, M.P., Sihite, E.I., & Suyanti, R.D. (2023). The effect of Blended learning with Edmodo-assisted scientific approach on independence and science learning outcomes. *International Journal of Instruction*. 16(4), 135-154. <https://doi.org/10.29333/iji.2023.1649a>.
- Vonganusith, V. Pagram, J. (2008) Web-based Courses to Support EFL Learning for Pre-service Teachers: A Thai Pilot Study. Conference Proceeding of International Conference. Sustainability in Higher Education: Directions for Change, Edith Cowan University, Perth Western Australia, pp 559-570.