



ICT Based Chemistry Learning Innovation To Improve Student's Creativity In The Digital Era

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Abstract: Information, Communication, and Technology (ICT) continue to develop in the digital era. In this digital era, all data will obtain easily online. The development of learning media can be applied in the presence of ICT. One of the subjects that can use ICT as a medium is chemistry. This study aimed to describe the role of ICT in chemistry learning to increase students' creativity. Methods of data collection are done by documentation and literature study. Data sources are obtained from references to research results, journal articles, and other related sources. The form of ICT development in the field of conventional to modern chemistry education is with chemistry e-modules, virtual laboratory applications with (Phet), applications for drawing chemical structures online with ChemDraw, Chem3D, Jmoll, Chem and Sketch, as well as making chemical animation videos with PowerPoint, Fillmora, Powtoon, Flash, etc. Based on the results and discussion, it can conclude that ICT innovation in the chemistry learning system could increase students' creativity in the digital era.

Keywords: ICT, chemistry learning, digital era, creativity

1. Introduction

The digital era is a challenge for educators and student character formation. Many students interact with technology, such as gadgets and the internet [1]. The digital era can be a companion in shaping students' character at school and home [2]. An educator who is also technologically proficient and can form new media in learning to attract more students to explore new things. The world is currently busy discussing the transition from the Industrial Revolution 4.0 era to the era of society 5.0, which has many changes and challenges [3]. The era of society 5.0 is an era that carries the concept of technology in a community centered on humans who also collaborate with various technological systems, ranging from AI or Artificial intelligence, IoT (Internet of things), robotics, and so on, where different kinds of technical systems are

used in everyday life, especially in social problems, both virtual and real [4]. The development of information, communication, and technology (ICT) in education can solve increasingly complex and growing learning problems because it has an interesting and innovative learning process that makes students play an active role in the learning process [5]. However, there are still a few schools that have made maximum use of ICT in learning activities. Teachers utilizing ICT-based learning media are striving to be more creative in developing learning methods and media that can stimulate students to play a role [6]. But in reality, even though teachers have used ICT-based learning media, the learning media are only limited to power points used to convey material in the teaching and learning process because of the teacher's lack of insight in developing media and making the process easier [7]. Thus, the use of learning media teachers use is still very minimal.

Education is not only aimed at increasing the competence of knowledge or science in students, but education also acts as an agent of change, changes in attitudes, thinking processes, and ability to solve problems [8]. Science is developing from time to time. The development of this science has the potential to create new technologies that mark the progress of the times. The developed technology has entered by digital stage. The existence of technology is currently considered important in human life as a supporter in carrying out various activities, both work, business, to educational activities [9]. As in the world of education, technology can overcome the problems that exist in it. In this case, technology is a substitute for facilities and infrastructure in education [10]. Technology is the result of the development of science, which is in the world of education [11]. Education also uses technology to be used as a support when implementing learning [12].

ICT consists of two aspects, namely information technology and communication technology. ICT or Information, Communication, and Technology is everything that includes all technical equipment used to process and convey quality information [13]. ICT has been widely used in all fields, including education [10]. Not a few have used ICT to overcome the problems that exist in the world of education, starting from the lowest level of education to the highest level of education. ICT can easily be accessed whenever and wherever and as desired. One of the subjects that can take advantage of ICT in chemistry.

According to several studies, many students think that chemistry subjects are not easy to understand, unpleasant, and the material is abstract [14]. Still, chemistry subjects are interesting subjects and fun if delivered correctly. One of the supporting factors of a teaching and learning activity is media and teaching materials. Teaching materials are materials presented by educators, which can be in the form of books or materials directly delivered by educators can improve students' critical thinking skills [8]. Chemistry is a branch of science that examines the structure, composition, properties, and changes of matter [15]. The topics in chemistry that are studied are very broad, such as the history of atoms, the particles that makeup atoms, how a compound can be formed, chemical reactions, and others [16].

Chemistry is not only limited to discussing how a reaction can occur but also discusses phenomena that are seen in everyday life [17]. Examples include burning wood, rusting iron, rotting food, and turning milk into yogurt. Some of these phenomena are some examples of chemistry in daily life [18]. Chemistry is often referred to as the center of science because chemistry bridges other sciences such as physics, biology, and geology. Chemistry education is a science that not only aims to improve students' competence in understanding science but also must be able to create ideas or works that can be useful for the next generation [19].

In the digital era, everyone cannot be separated from the term technology, especially the millennial generation. Therefore, chemistry educators adapt to the times by taking the initiative to use ICT as a media development material and teaching chemistry learning materials to suit their interests, for example, the use of chemical applications such as ChemDraw, Chem3D, Jmoll, Chem Sketch, and so on. Technology that is integrated with learning is one way to achieve learning objectives. It is very important to update the learning model to increase the effectiveness of the teaching and learning process and to develop the spirit of learning from students. This study aims to describe the role of ICT in chemistry learning to increase students' creativity.

2. Materials and Methods

This research used library research or literature review to review the results of different studies and gather data from different references and sources related to ICT Based Chemistry Learning Innovation To Improve Student's Creativity. The literature review is important because it can form a valuable basis and will contribute to further research. Research based on literature reviews obtained from books, journals, and a number of other sources attempts to analyze all the data gathered from various sources. This study used secondary data including various national data related to ICT, Chemistry Learning, Creativity and many other supplementary data using scientific journal search reference site by inputting keywords. In addition to descriptive data, this study also includes a variety of information from different types of documents such as scientific journals, national and international reports compiled from a number of sources and theories related to the study.

3. Results and Discussion

3.1 ICT (Information and Communication, Technology)

ICT stands for Information and Communication, Technology, namely Technology, Information, and Communication. ICT is a terminology that includes all technical tools that can process and distribute information through technology [20]. This ICT has several aspects. The first aspect is information technology, which relates to using assistive devices and managing the available information. The second aspect is communication technology, which relates to disseminating or distributing information through technology. All fields can use ICT. Such as work, business, industrial management, propaganda facilities, and education. ICT positively impacts all areas due to its extraordinary and efficient benefits. Almost everyone uses ICT to facilitate their affairs, including in learning chemistry.

ICT integrated chemistry learning positively influences student achievement and makes students actively involved in learning. Teachers can directly influence students' use of ICT and their beliefs about it [21]. The use of ICT can be successful if teachers need to have high proficiency in pedagogical and scientific knowledge. Schools can conduct training on the use of ICT so that prospective teacher are well trained by frequently using ICT in schools.

3.2 The Role of ICT in Chemistry Learning

Chemistry has at least three components that are its limits: 1) curiosity, critical thinking, and hard work, 2) theories, concepts, laws, principles, and 3) the scientific process [22]. These components must be owned by someone who wants to be a chemist. A chemist, when in the process of updating and discovering chemistry, uses a method known as the scientific method. The process in scientific method is that a chemist will first find a problem and then formulate a problem formulation by predicting how to solve it, analyzing the problem, conducting experiments, and concluding the experimental results. When the scientific method process is implemented, a chemist must include positive characteristics, such as hard work, care, diligence, thoroughness, honesty, responsibility, and other positive characteristics.

The development of technology and information in the era of society 5.0 caused a change in the teacher's mindset as the centre of learning. Now, it is replaced by students who have become the centre. Chemistry learning will be effective, collaborative, innovative, and active learning if it collaborates with advances in technology and information [23]. Chemistry learning that successfully collaborates with information technology will be one way to increase students' interest in learning and motivation and also improve students' critical thinking skills [24].

Entering the current era of globalization and digitalization, educators must prepare and adapt to create an enjoyable learning atmosphere [10]. Chemistry is often assumed to be an abstract science and difficult to understand because of the many sub-chapters studied in it [25]. Chemistry also looks at several phenomena that cannot be seen with the naked eye (abstract). It is necessary to have media or tools and adequate teaching materials. Chemistry is given to high school students or the equivalent. From some of the facts found and based on the research conducted, not a few high school students complained because they had difficulty understanding chemistry. Moreover, the learning method used is less supportive, making students less enthusiastic about learning chemistry subjects.

The education era has undergone many changes, where every learning activity will be more efficient with technology development. Chemistry learning activities must take advantage of the role of information and communication technology to increase efficiency and effectiveness. Like the current era of education, chemistry learning has been integrated with a curriculum designed with the aim that students can apply a disciplined, independent attitude and have a critical mindset. Media in education must also adjust according to the needs of students in the current era. Based on several studies that have been carried out, students will be more interested in subjects that are integrated with ICT. Such as chemistry subjects that can combine with technology.

The teaching and learning process is never far from learning problems [26]. The existence of learning media helps students to succeed in learning activities, especially chemistry [27]. Adopting and adapting to technology has led to the paradigm of "doing new things in new ways" or inquiry. The emergence of changes and shifts in learning paradigms affects all aspects of learning, including instructional rules and media development that must combine with technological developments. In the current era, ICT is a solution to the problems in education. ICT has several roles in developing chemistry learning to make it more exciting and attractive to many students. Here are some of the uses of ICT in chemistry learning [21].

a. E-Modules Instead Of Student Worksheets

The e-module development process involves programs and software such as Microsoft Office, Adobe Photoshop, Flipbook Maker Pro4, Quiz Creator, CorelDraw, Flash Player, Camtasia, etc. The output of the e-module is in the form of a digital book file. It contains chemical content with the exe and swf file extensions in this case. This interactive chemistry e-module development product must pass several stages of testing, namely a feasibility test (validation) from media and material experts and testing to students. chemistry learning e-modules are arranged based on the basic competencies of each level of education. The module is equipped with various components of teaching materials such as pictures, videos/animations and quizzes, as well as interactive features to attract students' attention and creativity. Its use

is effortless with just a gadget. Teachers and students can quickly learn and apply the material at school. Students can also use e-modules independently for self-study at home.

E-Modules are used as a substitute for teaching materials (such as worksheets) in chemistry learning based on ICT-based learning models [28]. E-Modules are electronic teaching materials that can download online on certain sites. E-Modules are almost the same as student handbooks in general, but the difference is that student handbooks are books in the form of printouts [29]. At the same time, E-Modules are materials accessed via the internet and can be accessed anywhere and anytime. E-Modules are considered very practical because access is very easy, especially in chemistry learning [30]. Students don't need to bother looking for references; internet access is enough. Teachers usually distribute these e-modules to their students via their respective class's Whatsapp groups or on the Google Drive page. So that students only through their separate gadgets can access it.

The following is an example of the cover of the e-module used as teaching material shown in Fig. 1.

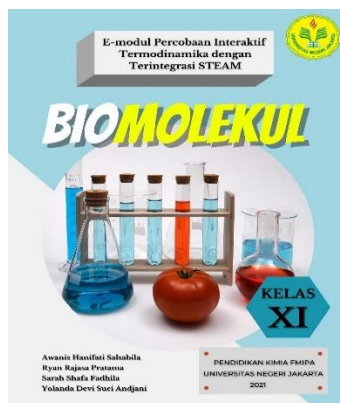


Fig. 1 - E-Module biomolekul

b. Use Of Virtual Laboratory Applications (Phet)

pHet is a virtual laboratory application accessed via the internet on certain websites [31]. This application makes it easy for students to do chemistry practicum without going to the Original Laboratory [32]. This digital-based media is useful as a supporting tool in teaching and learning activities to improve the learning process with higher quality. Like during the pandemic yesterday, when shifted all activities to online, this pHet is very helpful for carrying out practical activities even from their respective homes. This pHet application can be used for valuable learning without using original laboratory equipment [33]. pHet in chemistry learning can be used as an exciting learning medium to facilitate students in describing chemical reactions. [34]The pHet application makes it easy to describe molecular reactions directly, even though they are challenging to observe. With pHet, students can do practical simulations in their homes by connecting to the internet. Making chemistry practicum learning videos can also take advantage of pHet simulations. Students can explore and create laboratories according to the guidelines given by the teacher. The use of PhET also encourages students to further literacy by comparing several reading sources related to the results of practical simulations.



Fig. 2 - Phet application

c. Application Usage Of Drawing Chemical Compound Structure

Chemical applications used to draw the structure of chemical compounds include ChemDraw, Jmol, Chem 3D, and ChemSketch. Not only removing chemical structures, but this application can also be used to write chemical reactions,

including Lewis structures. Learning will be more interesting by using this application because students can practice directly while learning how to draw correct chemical compounds.

i. Chemdraw

Chemdraw is a chemical software product from Cambridgesoft. Inc. ChemDraw has many functions, including generating compound names and structures, correctly developing stereochemical forms from chemical names, calculating molecular formulas and molecular weights, and obtaining correct IUPAC names from structures. Estimated NMR spectra of the form of a compound with direct atoms by spectral correlation. In addition, ChemDraw comes with a warning if an error occurs in creating a chemical structure. The sign is usually red and surrounds the wrong part of the structure.

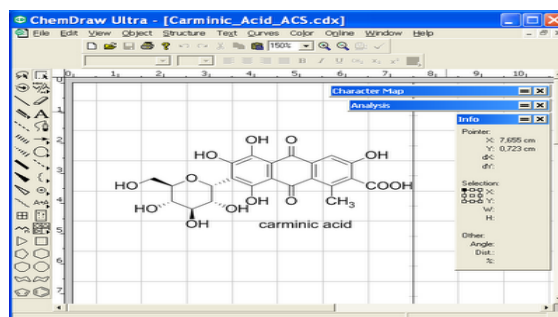


Fig. 3 - Chemdraw application

ii. Jmol

Jmol is an open-source Java viewer for three-dimensional chemical structures with features for chemicals, crystals, materials, and biomolecules. This software is for students, educators, and researchers in chemistry, biochemistry, physics, and materials science. Jmol returns 3D representations of molecules that can be used as teaching tools or for research, for example, chemistry and biochemistry. A popular feature is that it can integrate applets into web pages to display molecules in various ways. For example, molecules can be represented as ball-and-peg models, filled-space models, band diagrams, etc. Jmol supports a variety of chemical file formats, including Protein Data Bank (PDB), Crystallographic Information File (CIF), MDL Molfile (mol), and Chemical Markup Language (CML).

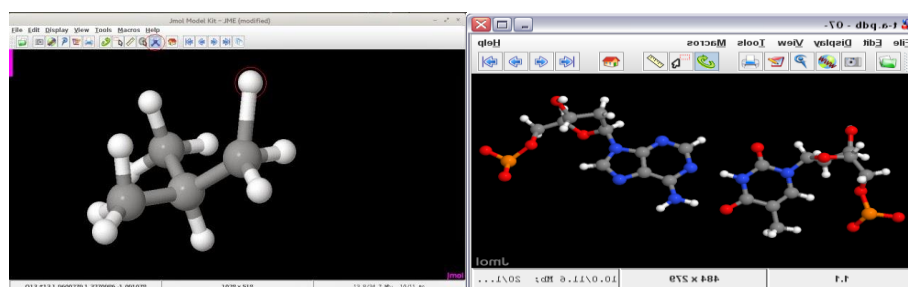


Fig. 4 - Jmol application

iii. Chem3D

Chem3D can be used to draw molecular structures in 3D (3D) and calculate minimum energies and bond lengths between atoms. It can remove certain common forms directly by clicking the tool, such as the ring structure of benzene, cyclopentane, cyclohexane, and other cyclic compounds. ChemDraw tools also provide structural images for the amino acids, DNA, and RNA contained in the template.

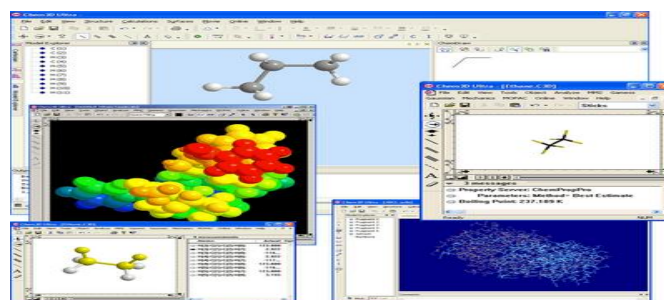


Fig. 5 - Chem 3D application

iv. ChemSketch

ChemSketch is a freeware software from ACD/Labs that can facilitate users who need to draw molecular structures, including organic molecular structures, organometallic compounds, polymers, and Markush structures. Molecular structure images that have been created in ChemSketch can be saved in ChemSketch Documents (*.sk2), Molfiles (*.mol), ChemDraw (*.cdx), Adobe document (*.pdf) formats, and several graphic data formats (*.BMP, *.gif, *.tif, *.png). ChemSketch helps depict molecules in chemistry learning, both at the high school, undergraduate, and postgraduate levels, making it easier to interpret molecular geometry for students and teachers.

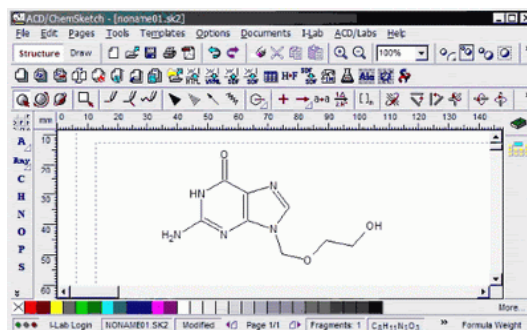


Fig. 6 - ChemsKetch application

d. Use of Animated Videos in Chemistry Learning

Educators will also be innovative in improving the learning media used in chemistry subjects [35]. Animated video applications are an example of the success of technology that can be used as an interesting learning medium and facilitate the delivery of material so that students receive subject matter more quickly [36]. Animated videos can help teachers to visualize abstract lesson material or concepts. Animated videos can be used as a medium for chemistry learning, and learning will be more creative and not boring. Animated video media combines other media elements such as audio, text, video, image, graphics, and sound to accommodate student learning styles that may have visual, auditory, or kinesthetic types [37]. Animated videos, if used as learning media, will prevent students from feeling bored and tired due to teacher explanations that are difficult to digest and understand. Chemical animation videos can be made by PowerPoint, Fillmora, Powtoon, Flash, etc.

i. PowerPoint

PowerPoint or PPT is one of the popular software or applications and is very well known by everyone. Teachers can make learning videos with Powerpoint media by displaying material in the form of videos [27]. Students will be more enthusiastic when listening to the subject matter. There are various powerful features when it comes to making learning videos using PowerPoint. Teachers, lecturers, students, the community, and students can use this feature to create learning videos. Presentation of PowerPoint looks more attractive because of animated images or photos, letters and animations, and color games. It will make learning look more professional and interesting. Powerpoint slides that have been made can be directly shared in learning videos. Teachers can develop and collaborate with other fellow teachers to present various kinds of content in the world of education, especially in chemistry[38].



Fig. 7 - Powerpoint application

ii. Filmora

One of the lightweight and easy-to-learn video editing applications is Wondershare Filmora. This application has the appearance and features as needed [39]. Filmora has a simple interface, and various tools are easily recognized so that teachers and students are more flexible and easy to edit videos [40]. One of the advantages of this application is that you can use all of the existing features without paying. After editing the video, we can export your edits to various available options, such as file format, video resolution, frame rate, and bit rate [41]. Then you can choose the video quality according to the device or social media you want, for example, smartphones, game consoles, TV, Youtube, Vimeo, iPod, or smart TV. Filmora can be used to make chemistry learning videos.



Fig. 8 - Filmora application

iii. Powtoon

Powtoon is a simple web-based application used to create attractive animated videos quickly [42]. This application is connected to the internet or online web apps that can present presentations or presentations of material. The display is in the form of a video containing various animations that can attract students' attention [43]. Powtoon can be used to make chemistry learning videos. Through Powtoon media, it is hoped that it will make it easier for educators to make chemistry subject matter that looks interesting and creative. Besides making it easier for educators, in this case, namely teachers, Powtoon is also expected to make students more enthusiastic about listening to the material presented by the teacher. This Powtoon learning media has advantages, namely the many various animation features and effects that make presentations or learning videos look interesting [44]. In addition, the timeline contained in Powtoon can also be used easily compared to other similar applications.



Fig. 9 - Powtoon application

iv. Flash Application

Flash application is a learning media that contains animation with video, text, images, graphics, and sound quickly and easily [45]. This Flash Application is expected to make students more interested in participating in chemistry learning [36]. The use of flash application-based learning videos in the learning process is very helpful in increasing the effectiveness and efficiency of the teaching process and learning outcomes. In addition, the use of learning media, especially flash applications, can increase the attractiveness and motivation of students to participate in the chemistry learning process.



Fig. 10 - Flash application

4. Conclusion

ICT has several roles in developing chemistry learning to make it more interesting and attractive to many students. Educators should be experts in using ICT in learning to improve the quality of learning so that students will easily understand the learning process. Chemistry learning media must adjust according to the needs of students in the current era. The development of ICT in chemistry learning includes E-modules used as a substitute for teaching materials (student worksheets) in learning chemistry, Use of Virtual Laboratory Applications (Phet), Use of Drawing Applications for Chemical Compound Structures (ChemDraw, Jmol, Chem 3D, and ChemSketch), and Use of Animation Videos in Chemistry Learning (powerpoint, fillmora, powtoon, flash). Animated videos can be used as a medium for chemistry learning, and learning will be more creative and not boring. Virtual laboratory applications for chemistry can make students understand more about practical activities without having to practice them directly in the laboratory. Using ICT-based learning media in chemistry learning can increase the attractiveness and motivation of students to participate in teaching and learning activities in the digital era. Further research is needed to analyze the effect of ICT-based chemistry learning media on students' critical thinking skills by applying an interactive learning model.

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