JTK: Jurnal Tadris Kimiya 7, 2 (December, 2022): 266-276
Website: http://journal.uinsgd.ac.id/index.php/tadris-kimiya/index
ISSN 2527-9637 **(online) ISSN** 2527-6816 **(print)**

Development of Intertextual-Based E-Book on the Concept of Buffer Solution

***Nur Sehasari Dewi*[1*]**
[1]Department of Chemical Education, Faculty of Mathematics and Science, Indonesia Education University, Bandung 40154, Indonesia
[*]E-mail: nur21@upi.edu

Received: 19 November 2022; Accepted: 23 December 2022; Published: 31 December 2022

Abstract

Students are necessary to understand macroscopic, sub-microscopic, and symbolic representations levels in buffer solution concept. The research aims to develop the intertextual based e-book on the concept of buffer solution. The study is part of the research and development plan for creating teaching materials. Stages of research are conducted as follows research and information collecting, planning, and developing the preliminary form of product. Based on the result, the product of teaching material has characteristic, which is connecting the three levels of chemical representation on the buffer solution concept. Due to their visualization character and multiple representational relationship, interactive e-books demonstrate the power and value of modeling, learning, and assessment perspectives. Intertextual e-books potential to be implemented as teaching materials in buffer solution concepts.

Keywords: buffer solution, interactive, representation, visualization

DOI: https://doi.org/10.15575/jtk.v7i2.21235

1. Introduction

Chemistry has phenomena that can be observed with the naked eye and require explanation at the molecular level that the eye cannot observe (Talanquer, 2011). Chemical phenomena can be explained by three levels of representation: macroscopic, sub-microscopic, and symbolic levels (Stojanovska et al., 2014). The representation is a way to express phenomena, objects, events, abstract concepts, ideas, processes, mechanisms, and systems (Wu et al., 2001).

Chemists use all three levels of representation and link between levels of representation in order to form a concept. Students have to understand the representation levels and their relationship of those levels in the process of presenting scientific knowledge (Ainsworth, 1999; Jaber & BouJaoude, 2012).

The buffer solution is one of the most complex chemical concepts at the student level. It is a concept discussed in many chemistry courses and used in various types of laboratory research, so it is essential to understand the concept of buffer solutions at the high school level (Orgill & Sutherland, 2008). Based on Melinda's research (2022), students' difficulties in buffer solutions are distinguishing acid, base, or salt compounds, and they need help understanding the concept of acid-base in the previous material. Consequently, students need to pay more attention to the number of moles in each compound in acid-base reactions. Therefore, students need help determining the concept of a buffer solution. Besides, they require help understanding the variables in the buffer solution formula and only enter numbers into the existing formula to solve the calculation problem without paying attention to the nature of the solution due to students needing help analyzing the buffer solution and not the buffer solution.

The student’s difficulties in understanding the concept of the buffer solution are because students need help to connect the three levels of abstract chemical representation (Orgill & Sutherland, 2008). Students must explain chemical processes verbally (Kozma & Russell, 1997). Moreover, doing translations between different types of representations. It shows a need for more relationships between chemical phenomena, representations, and relevant concepts (Kozma, 2000).

Several studies have stated that students' difficulties in understanding the level of representation can lead to misconceptions (Chittleborough & Treagust, 2007; Gkitzia et al., 2011). Some misconceptions are caused by the inability of students to visualize structures and processes at the submicroscopic or molecular level (Tasker & Dalton, 2006). In a related study, Smith & Metz (1996) concluded that the chemistry teaching strategy uses microscopic visual aids that can explain chemical concepts before applying mathematical calculations.

Furthermore, overcoming misconceptions and producing successful chemistry learning involves building mental associations between macroscopic, microscopic, and symbolic levels of representation of chemical phenomena using various modes of representation (Cheng & Gilbert, 2009). In studying chemistry, students reconstruct an understanding that can link the three levels of representation so that learning will be more meaningful (Sulistyowati & Poedjiastoeti, 2013). The relationship between representations in chemistry can be viewed as an intertextual relationship (Wu, 2003).

Intertextual learning strategy is a learning strategy that can accommodate the three levels of representation in chemistry and link the relationship between the three so that students can understand the concept of chemistry as a whole. Intertextual can be a learning strategy for students to build understanding through various levels of chemical representations that are relevant to students' everyday experiences (Wu, 2003). Intertextual learning allows students to visualize chemistry concepts and improve conceptual understanding (Kozma & Russell, 1997). Thus, it is essential to learn through visualization of objects in the surrounding environment that must be realized in order to clarify understanding quickly, increase the interest, and genuine involvement of students (Tan & Waugh, 2014).

Various multimedia tools have been designed to help students visualize invisible chemical entities (atoms and molecules) represented by chemical symbols and to develop their understanding of representation-level relationships (Pallant & Tinker, 2004; Wu et al., 2001). Multimedia tools have demonstrated their power and value for modeling, learning, and assessment perspectives due to the nature of visualization, multiple links, and multiple and dynamic representations (Kozma & Russell, 1997). These characteristics foster conceptual understanding and the relationship between symbolic representation and problem-solving.

To deal with this phenomenon, an interactive e-book is one of the learning resources containing multimedia (Munir, 2009). E-books have become digital books with advanced technology, which are expected to develop to replace traditional books in the future (Lai & Chang, 2011; Lynch, 2012). Interactive e-books are digital books where users can interact and communicate reciprocally (Ohene-Djan & Fernandes, 2003). Interactive e-books use multimedia elements that provide rich communication opportunities to enhance the learning experience and provide effective, efficient, and exciting learning opportunities (Bozkurt & Bozkaya, 2015).

The interactive e-book is an interactive e-book that serves as a learning resource accompanied by pictures, videos, animations, and interactive practice questions that allow students to write answers directly in the e-book (Vassiliou & Rowley, 2008; Huda et al., 2015). In this paper, the material content analysis of buffer solution concepts uses multiple chemical representations aimed at developing of teaching materials. Thus, e-book can help visualize and relate the three levels of abstract chemical representations.

2. Research Method

The research method used is the research and development (R&D) method proposed by Borg and Gall with the aim of developing and validating the product being developed. Borg and Gall describe the steps in research and development as cyclical with 10 main steps namely: research and information collecting; planning; develop preliminary form of product; preliminary field testing; conduct main product revision; main field testing collecting; revision of product; operational field testing; final product revision; and dissemination and implementation (Sugiyono, 2013).

In this research, up to 3 research steps were carried out in the Borg and Gall research model on the initial product development of an intertextual-based prototype e-book on the concept of a buffer solution. On this development, application or the programs used are Canva and Heyzine Flipbook.

3. Result and Discussion

3.1. Develop the Initial Product of Intertextual-Based E-Book

The construction of the e-book consists of three parts: introduction, primary materials, and conclusion. Introduction part is shown in Figure 1.

Figure 1. E-book Cover

Primary materials part consists of the meaning, components, working principle, calculate the pH, and the application of buffer solution in life. Figure 2 show the primary materials part of the intertextual e-book on the buffer solution concept.


LARUTAN PENYANGGA DAPAT DIBUAT DENGAN 2 CARA :

1. A. Mencampur langsung asam lemah (CH_3COOH) dan basa konjugat (CH_3COO^-) dalam bentuk garam $NaCH_3COO$

VISUALISASI PEMBUATAN LARUTAN PENYANGGA DARI ASAM LEMAH DAN GARAM KONJUGATNYA

Figure 2. Primary Materials Part of the Intertextual E-book

Figure 3 shows the overview of an intertextual-based e-book that can visualize three levels of representation. The description of the e-book becomes a reference for making an interactive-based e-book on the buffer solution concept.

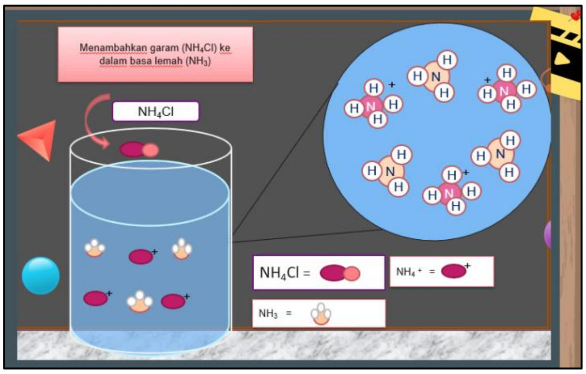


Figure 3. Visualization of Three Levels of Representation in an Intertextual-based E-book

Chemistry has three levels of representation: macroscopic, sub-microscopic, and symbolic. Therefore, students must be taught explicitly about these three levels and the relationships between the three levels (Harrison & Treagusf, 2002).

Macroscopic representation is a chemical representation obtained through actual observations of a phenomenon that can be seen and perceived by the five senses (sensory level), either directly or indirectly. Observations can be obtained through daily experience, laboratory investigations, field studies, or simulations. For example, changes in color, temperature, pH of the solution, and the formation of gases and precipitates can be observed when a chemical reaction occurs (Hidayanti & Rosilawati, 2018).

Submicroscopic representation is a chemical representation that explains the structures and processes at the particle (atomic or molecular) level of the observed macroscopic phenomena. The term submicroscopic refers to a smaller size than the nanoscopic level. The submicroscopic level of representation based on particulate matter theory is used to explain macroscopic phenomena in terms of the motion of particles, such as the motions of electrons, molecules, and atoms. These submicroscopic entities are real but too small to be observed (Varelas & Pappas, 2006).

Symbolic representations are qualitative and quantitative chemical representations, chemical formulas, diagrams, pictures, reaction equations, stoichiometry, and mathematical calculations. To understand the learning process, the ability to transfer and connect between the three levels of representation is needed (Farida et al., 2018). According to Davidowitz and Chittleborough (2009), the relationship between the three levels of representation can be illustrated in Figure 4.

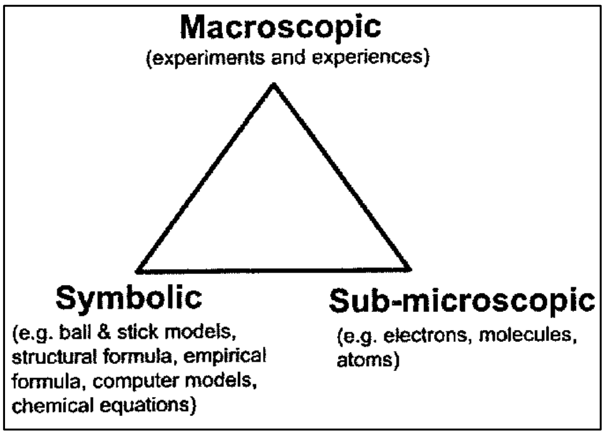


Figure 4. The Relationship Between Three Levels of Representation of Chemistry Learning (Davidowitz & Chittleborough, 2009)

Understanding the concept will be more easily explained in chemistry learning by connecting these representations.

Chemists currently use microscopic representations arising from the phenomenological analogy of sensory experience at the macroscopic level. However, microscopic understanding and symbol representation are difficult for students. Students' difficulty studying microscopic representations and symbols is caused by these representations being invisible and abstract. In contrast, students' understanding of chemistry is generally based on things that can be seen (Wu et al., 2001). Hence, the submicroscopic level requires the ability to imagine and visualize concepts that are not seen.

Words (verbal), diagrams/pictures, two-dimensional models, and three-dimensional models, both still and moving, can all be used to express representational abilities (in the form of animation). In science learning, it is essential to emphasize the role and purpose of scientific models and then provide examples or opportunities to build model-based cognitive tools for studying science (Treagust et al., 2003).

Based on Gilbert's research (2008) claims that visualization, through multimedia, combines mental images, which are generated in the process of understanding objects seen or touched, into a phenomenon. Model-based teaching and learning facilitate the construction of mental models through a recursive process of formation, use, versioning, and elaboration.

Chemical reactions in the body of living things are enzymatic reactions involving enzymes and catalysts. Enzymes as catalysts can only work well at a specific pH. Meanwhile, the oxygen binding reaction of the blood is at an average pH of around 7.35-7.45.

Consequently, any difference from this range can negatively affect cell membranes, protein structure, and activity. Death can occur if the blood pH falls below 6.8 or rises above 7.8. When the pH drops below 7.35, this condition is called acidosis; when it rises above 7.45, it is called alkalosis. Acidosis is a common tendency we experience because metabolism produces some acid (Brown et al., 2009).

Chemical reactions in the body of living things are enzymatic reactions involving enzymes and catalysts. Enzymes as catalysts can only work well at a specific pH. Meanwhile, the oxygen binding reaction of the blood is at an average pH of around 7.35-7.45. Consequently, any difference from this range can negatively affect cell membranes, protein structure, and activity. Death can occur if the blood pH falls below 6.8 or rises above 7.8. When the pH drops below 7.35, this condition is called acidosis; when it rises above 7.45, it is called alkalosis. Acidosis is a common tendency we experience because metabolism produces some acid (Brown et al., 2009).

A buffer solution is a solution that can withstand drastic changes in pH when small amounts of strong acid, strong base, and dilution are added to it (See Figure 5). When a pH 5 buffer solution is added to 1 ml of 1 M HCl and 1 ml of 1 M NaOH, the pH that occurs is relatively constant (Silberberg, 2010).

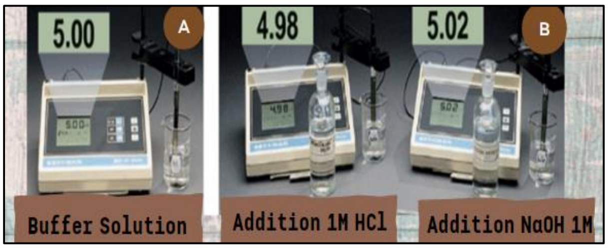


Figure 5. Effect of Addition of Small Amounts of Acid and Base on the pH of the Buffer (Silberberg, 2010).

Unlike with non-buffer solutions, the pH will change drastically when a small amount of acid or base is added. Look at Figure 6; when a robust acid solution of 100 ml of HCl pH 5 is added to 1 ml of 1M HCl, the pH of the solution drops to 2. On the other hand, if 1 ml is added NaOH 1M, the pH of the solution rises drastically to 12.

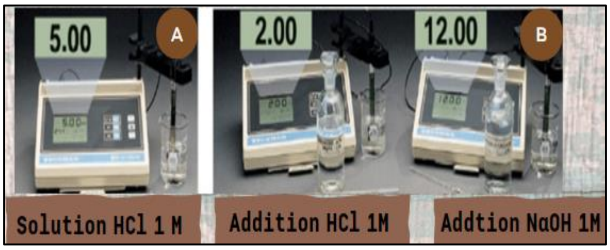


Figure 6. Effect of adding a small amount of strong acid and a strong base on a solution of a strong acid (not a buffer) (Silberberg, 2010).

The buffer solution can withstand changes in pH because it contains an acidic component to neutralize the added OH ion and an alkaline component to neutralize the added H+ ion. The buffer solution component consists of two solutes, one weak acid, and its conjugate base or a weak base and its conjugate acid (Silberberg, 2010).

Buffer solutions contain solutes that allow them to withstand significant changes in pH when large amounts of a strong acid or strong base are added. Based on the components of the mixed solute, there are two types of buffer solutions: acid buffer and alkaline buffer. This requirement is met by a pair of conjugate acids, weak acids such as CH_3COOH / CH_3COO or conjugate base, and weak bases such as NH_4^+/NH_3.

Thus, a buffer solution can be prepared by mixing a weak acid or a weak base with a salt of that acid or base (Jespersen et al., 2012).

The CH_3COOH/CH_3COO buffer can be prepared, for example, by adding CH3COONa to the CH_3COOH solution. An NH_4^+/NH_3 buffer can be prepared by adding NH_4Cl to an NH_3 solution. All of us can buffer solutions at almost any pH by selecting the right components and adjusting their relative concentrations (Jespersen et al., 2012).

The pH value of a solution is determined by the concentration of H^+ and OH^- ions present in the solution. Adding a strong acid and a strong base can affect the change in the pH of the solution, but this does not affect the pH of the buffer solution if it added in small amounts. It is causes due to the buffer solution's working system that can eliminate or reduce the effect of added H^+ and OH^- ions. Note in Figure 7, it is illustrated how a buffer solution can reduce the effect of adding acid and base to an acid buffer solution.

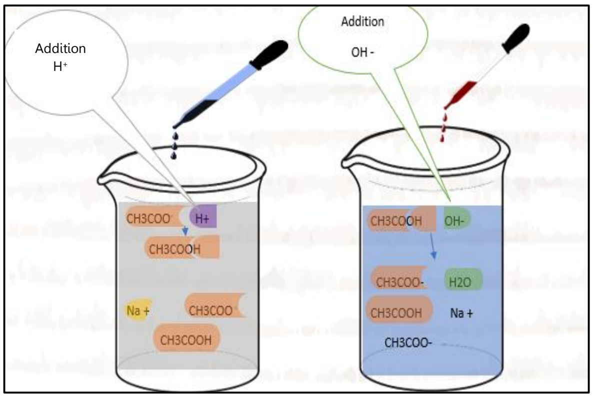


Figure 7. Model Depicting the Addition of A Strong Acid [H^+] and the Addition of Strong base [OH^-] in an Acid Buffer Solution with low concentrate (Silberberg, 2010).

The workings of buffer solutions can be explained through a phenomenon known as the common-ion effect (Silberberg, 2010). An example of a common ion or common-ion effect occurs when acetic acid dissociates slightly in water.

$$CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftarrows H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

From Le Chatelier's principle, it is known that if some CH_3COO^- ions are added (from dissolved sodium acetate), the equilibrium position shifts to the left, and thus $[H_3O^+]$ decreases, consequently lowering the acid dissociation rate.

$$CH_3COOH_{(aq)}+H_2O_{(l)} \overset{\longleftarrow}{\rightleftarrows} H_3O^+_{(aq)} + CH_3COO^-_{(aq)}$$

Similarly, if we dissolve acetic acid in sodium acetate solution, the acetate ions and H_3O^+ ions from the acid enter the solution. The acetate ion in the solution prevents the acid from dissociating like pure water, thereby lowering $[H_3O^+]$. In this case, the acetate ion is called the namesake ion for acetic acid and sodium acetate solution. The namesake ion effect occurs when a particular ion is added to an equilibrium mixture that already contains that ion. Look at Figure 8, the position of the equilibrium shifts from that of its constituent (Silberberg, 2010).

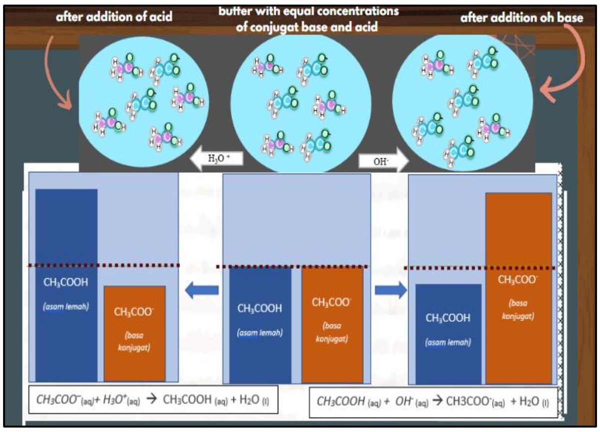
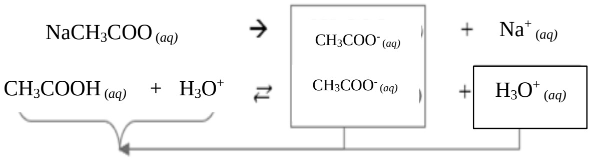


Figure 8. The Effect of Addition of Acid (H^+) and Base (OH^-) on Acid Buffer System (Silberberg, 2010).

The equilibrium of the acid buffer, which consists of a weak acid (HX) and a conjugate base (X^-), will form an equilibrium reaction, for example, in CH_3COOH and ionized $NaCH_3COO$ as follows (Whitten, 2014):



$$NaCH_3COO_{(aq)} \rightarrow CH_3COO^-_{(aq)} + Na^+_{(aq)}$$

$$CH_3COOH_{(aq)} + H_3O^+ \rightleftarrows CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$$

Both CH_3COOH and $NaCH_3COOH$ are sources of the CH_3COO^- ion. $NaCH_3COOH$ solution dissociates completely and produces high CH_3COO^- that shifts the CH_3COOH equilibrium to the left because CH_3COO^- combines with H_3O^+ to form CH_3COOH and H_2O; the result is a drastic decrease in H_3O^+ (Whitten et al., 2014). The Ka equation is as follows:

$$Ka = \frac{[CH3COO^{-}]\,[H_3O^{+}]}{[CH3COOH]}$$

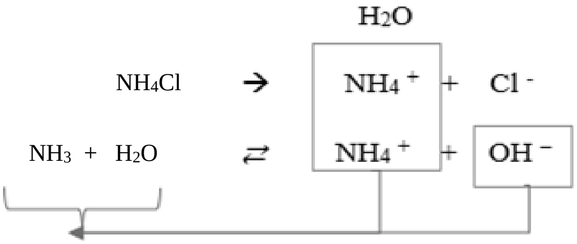
$$[H_3O^{+}] = \frac{[CH3COOH]\ Ka}{[CH3COO^{-}]}$$

Or the equation $[H^+]$ can be written:

$$[H^{+}] = Ka\,\frac{[acid]}{[conjugate\ base]}$$

$$[H^{+}] = Ka\,\frac{[mol\ acid]}{[mol\ conjugate\ base]}$$

For a fundamental support, which contains a weak base (NH_3) and the conjugate base of a salt (NH_4Cl), by an ionic reaction similar to that of basic support, it looks (Whitten, 2014):



Both NH_4Cl and aqueous NH_3 are sources of NH_4^+ ions. NH_4Cl completely dissociates to give high NH_4^+, thus shifting the equilibrium to the left, as NH_4^+ ions combine with OH^- ions to form un-ionized NH_3 and H_2O, resulting in a significant reduction in OH^- (Whitten et al., 2014). The equation for Kb is as follows:

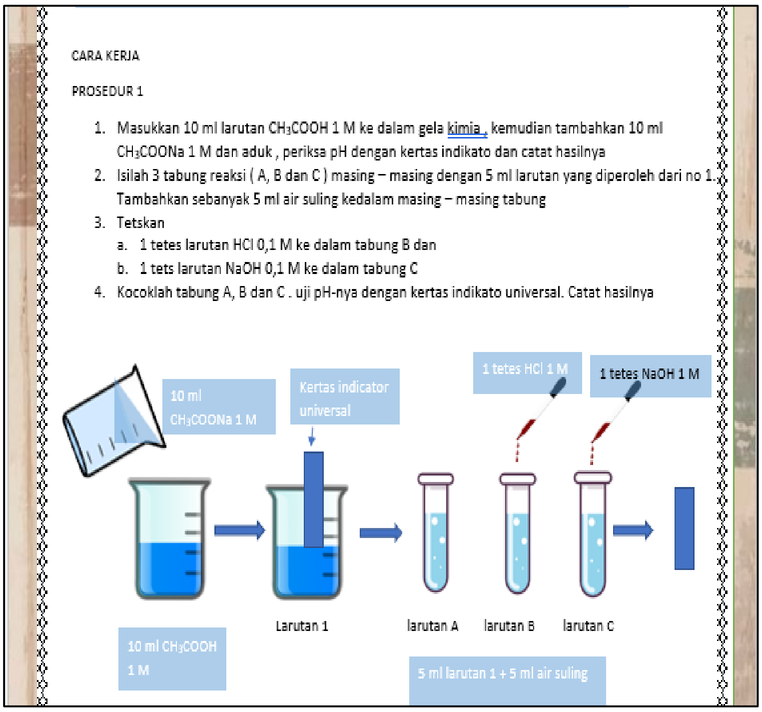
$$Kb = \frac{[NH_4^{+}]\,[OH^{-}]}{[NH_3]}$$

$$[OH^{-}] = Kb\,\frac{[NH_4^{+}]}{[NH_3]}$$

$$[OH^{-}] = Kb\,\frac{[base]}{[conjugate\ acid]}$$

$$[OH^{-}] = Kb\,\frac{[mol\ base]}{[mol\ conjugate\ acid]}$$

Figure 9 and 10 show the conclusion part of the intertextual e-book.



CARA KERJA

PROSEDUR 1

1. Masukkan 10 ml larutan CH_3COOH 1 M ke dalam gela kimia , kemudian tambahkan 10 ml CH_3COONa 1 M dan aduk , periksa pH dengan kertas indikato dan catat hasilnya
2. Isilah 3 tabung reaksi (A, B dan C) masing – masing dengan 5 ml larutan yang diperoleh dari no 1. Tambahkan sebanyak 5 ml air suling kedalam masing – masing tabung
3. Tetskan
   a. 1 tetes larutan HCl 0,1 M ke dalam tabung B dan
   b. 1 tets larutan NaOH 0,1 M ke dalam tabung C
4. Kocoklah tabung A, B dan C . uji pH-nya dengan kertas indikato universal. Catat hasilnya

Figure 9. E-book Practical Part of Buffer Solution

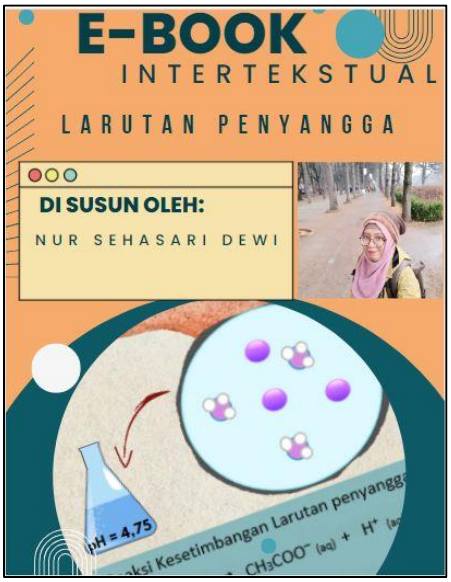


Figure 10. Back Cover of E-book Practical Part of Buffer Solution

Conclusion part of the developed e-book consists of form evaluation questions, practicum assignments, bibliography, and back cover.

4. Conclusion

The e-book can visualize abstract chemical concepts and relationships between levels of representation that have the potential to be implemented as teaching materials in the concept of buffer solutions. Interactive multimedia capabilities can display words, images, and two/three-dimensional models, both still and moving (in animation). It can improve students' representational abilities in the concept of buffer solutions.

References

Ainsworth, S. (1999). The functions of multiple representations. *Computers & education*, *33*(2-3), 131-152. Retrieved from www.elsevier.com/locate/compedu.\

Bozkurt, A., & Bozkaya, M. (2015). Evaluation Criteria for Interactive E-Books for Open and Distance Learning. *International Review of Research in Open and Distributed Learning*, *16*(5), 58–82. Retrieved from https://files.eric.ed.gov/fulltext/EJ1077792.pdf

Brown T. L. LeMay J. H. E. Bursten B. E. Murphy C. J. & Woodward P. (2009). *Chemistry: the central science - 12th edition* (12th ed.). United State: Pearson Prentice Hall.

Cheng, M., & Gilbert, J. K. (2009). Towards a Better Utilization of Diagrams in Research into the Use of Representative Levels in Chemical Education. In *Multiple Representations in Chemical Education*, 55–72. Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-8872-8.

Chittleborough, G., & Treagust, D. F. (2007). The Modelling Ability of Non-major Chemistry Students and Their Understanding of The Sub-microscopic Level. *Chemistry education research and practice*, *8*(3), 274-292. https://doi.org/https://doi.org/10.1039/B6RP90035F

Davidowitz, B., & Chittleborough, G. (2009). Linking the Macroscopic and Sub-microscopic Levels: Diagrams. In *Multiple Representations in Chemical Education*, 169–191. Netherlands Springer. https://doi.org/10.1007/978-1-4020-8872-8_9

Farida, I., Helsy, I., Fitriani, I., & Ramdhani, M. A. (2018). Learning Material of Chemistry in High School Using Multiple Representations. In *IOP Conference Series: Materials Science and Engineering* (Vol. 288, No. 1, p. 012078). IOP Publishing. Retrieved from http://digilib.uinsgd.ac.id/5760/

Gilbert, J. K. (2008). Visualization: An Emergent Field of Practice and Enquiry in Science Education. In *Visualization: Theory and Practice in Science Education* (pp. 3–24). Dordrecht: Springer. https://doi.org/10.1007/978-1-4020-5267-5_1

Gkitzia, V., Salta, K., & Tzougraki, C. (2011). Development and Application of Suitable Criteria for The Evaluation of Chemical Representations in School Textbooks. *Chemistry Education Research and Practice*, *12*(1), 5–14. https://doi.org/10.1039/c1rp90003j.

Harrison, A. G., & Treagusf, D. F. (2002). The Particulate Nature of Matter: Challenges in Understanding the Submicroscopic World. In *Chemical Education: Towards Research-based Practice* (pp. 189–212). Dordrecht: Springer. https://doi.org/10.1007/0-306-47977-X_9

Hidayanti, U., & Rosilawati, I. (2018). Pengembangan E-book Interaktif Berbasis Representasi Kimia pada Materi Larutan Penyangga. *Journal Pendidikan Dan Pembelajaran Kimia*, *7*(2), 1-12. Retrieved http://jurnal.fkip.unila.ac.id/index.php/JPK/article/view/14999

Huda, T. A., Fadiawati, N., & Tania, L. (2015). Pengembangan E-book Interaktif pada Materi Termokimia Berbasis Representasi Kimia. *Jurnal Pendidikan dan Pembelajaran Kimia*, *4*(2), 530-542. Retrieved from http://jurnal.fkip.unila.ac.id/index.php/JPK/article/view/9404

Jaber, L. Z., & BouJaoude, S. (2012). A Macro-Micro-Symbolic Teaching to Promote Relational Understanding of Chemical Reactions. *International Journal of Science Education*, *34*(7), 973–998. https://doi.org/10.1080/09500693.2011.569959

Jespersen, N., Brady, J., & Hyslop, A. (2012). *Chemistry The Molecular Nature of Matter*. USA: John Willey & Sons, Inc.

Kozma, R.B. (2000). Students Collaborating with Computer Models and Physical Experiments. In C. Hoadley (Ed.), *Computer support for collaborative learning*. Mahwah, NJ: Erlbaum. https://doi.dx.org/10.22318/cscl1999.439

Kozma, R.B., Chin, E., Russell, J., & Marx, N. (2000). The Roles of Representations and Tools in The Chemistry Laboratory and Their Implications for Chemistry Instruction. *Journal of the Learning Sciences*, 9(2), 105 - 143. Retrieved https://www.jstor.org/stable/1466853

Kozma, R. B., & Russell, J. (1997). Multimedia and Understanding: Expert and Novice Responses to Different Representations of Chemical Phenomena. *Journal of Research in Science Teaching*, *34*(9), 949–968. Retrieved from https://eric.ed.gov/?id=EJ557519

Lai, J. Y., & Chang, C. Y. (2011). User Attitudes Toward Dedicated E-Book Readers for Reading: The Effects of Convenience, Compatibility and Media Richness. *Online Information Review*, *35*(4), 558–580. https://doi.org/10.1108/14684521111161936

Lynch, K. (2012). E-books: The Future for Publishers and Libraries. *Collection Building*, *31*(2), 78–80. https://doi.org/10.1108/01604951211229872

Munir. (2009). *Pembelajaran Jarak Jauh Berbasis Teknologi Informasi dan Komunikasi (TIK)*. Bandung: Penerbit Alfabeta.

Ohene-Djan, J., & Fernandes, A. A. A. (2003). Personalising Electronic Books. *Journal of Digital Information*, *3*(4). Retrieved from https://journals.tdl.org/jodi/index.php/jodi/article/view/jodi-103

Orgill, M. K., & Sutherland, A. (2008). Undergraduate Chemistry Students' Perceptions of and Misconceptions about Buffers and Buffer Problems. *Chemistry Education Research and Practice*, *9*(2), 131–143. https://doi.org/10.1039/B806229N

Pallant, A., & Tinker, R. F. (2004). Reasoning With Atomic-Scale Molecular Dynamic Models. *Journal of Science Education and Technology*, *13*(1), 51–66. https://doi.org/10.1023/B:JOST.0000019638.01800.d0

Silberberg, M. S. (Martin S. (2010). *Principles of general chemistry* (2nd ed.). USA: McGraw-Hill.

Smith, K. J., & Metz, P. A. (1996). Evaluating student understanding of solution chemistry through microscopic representations. *Journal of Chemical Education*, *73*(3), 233. https://doi.org/10.1021/ED073P233

Stojanovska, M., Petruševski, V. M., & Šoptrajanov, B. (2017). Study of The Use of The Three Levels of Thinking and Representation. *Contributions, Section of Natural, Mathematical and Biotechnical Sciences*, *35*(1).http://dx.doi.org/10.20903/csnmbs.masa.2014.35.1.52

Sugiyono, D. (2013). *Metode penelitian pendidikan pendekatan kuantitatif, kualitatif dan R&D*. Bandung: Alfabeta.

Sulistyowati, T., & Poedjiastoeti, S. (2013). Kelayakan Multimedia Interaktif Berbasis Intertekstual pada Materi Reaksi Kimia untuk Kelas X SMA. *Unesa Journal of Chemical Education*, *2*(3), 57–63. Retrieved from https://jurnalmahasiswa.unesa.ac.id/index.php/journal-of-chemical-education/article/view/4469

Talanquer, V. (2011). Macro, Submicro, and Symbolic: The Many Faces of The Chemistry "Triplet." *International Journal of Science Education*, *33*(2), 179–195. https://doi.org/10.1080/09500690903386435

Tan, S., & Waugh, R. (2014). Use of Virtual Reality in Teaching and Learning Molecular Biology. In *3D Immersive and Interactive Learning* (pp. 17–43). Springer Singapore. https://doi.org/10.1007/978-981-4021-90-6_2

Tasker, R., & Dalton, R. (2006). Research Into Practice: Visualisation of the Molecular World using Animations. *Chemistry Education Research and Practice*, *7*(2), 141–159. https://doi.org/10.1039/B5RP90020D

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2003). The Role of Submicroscopic and Symbolic Representations in Chemical Explanations. *International Journal of Science Education*, *25*(11), 1353–1368. https://doi.org/10.1080/0950069032000070306

Varelas, M., & Pappas, C. C. (2006). Intertextuality in Read-alouds of Integrated Science-literacy Units in Urban Primary Classrooms: Opportunities for The Development of thought and Language. *Cognition and Instruction*, *24*(2), 211–259. https://doi.org/10.1207/s1532690xci2402_2

Vassiliou, M., & Rowley, J. (2008). Progressing the Definition of "E-book." *Library Hi Tech*, *26*(3), 355–368. https://doi.org/10.1108/07378830810903292

Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2014). *Chemistry* (10th ed.). USA: Mary Finch.

Wu, H. K. (2003). Linking the Microscopic View of Chemistry to Real-Life Experiences: Intertextuality in a High-School Science Classroom. *Science Education*, *87*(6), 868–891. https://doi.org/10.1002/sce.10090

Wu, H.-K., Krajcik, J. S., & Soloway, E. (2001). Promoting Understanding of Chemical Representations: Students' Use of a Visualization Tool in the Classroom. *Journal of Research in Science Teaching*, *38*(7), 821–842. https://doi.org/10.1002/tea.1033

Zhang, D. (2005). Interactive Multimedia-Based E-Learning: A Study of Effectiveness. *International Journal of Phytoremediation*, *21*(1), 149–162. https://doi.org/10.1207/s15389286ajde1903_3