



A Reconstruction of Boiling Point Elevation Apparatus

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Abstract: The aim of this study is identifying how to solve students' misconceptions on the topic of (H₂S) problem by conducting boiling point elevation experiments. This research was conducted into two steps. Firstly, proved the construction error of the boiling point in LabMaya. Secondly, is the to overcome it. In the first step, a real experiment was conducted based on the simulation in LabMaya. In the second step using the reconstructed set of tools. Results of the data analysis showed that the LabMaya construction proved to cause a very large reduction in solvent. The errors were 27.63%, 33.33%, and 40.75%, respectively. The reconstructed device proved to be able to maintain the amount of solvent so that it would not change the concentration of the solution. This equipment has a very small error, less than 5%. Of the three condensers used, namely Vigreux, Liebig, and Graham, it was found that the Graham condenser had the best accuracy

Keywords: Boiling point; Misconception; Reconstruction apparatus; Virtual lab

Introduction

Physical properties of solutions are depend to the number, not the kind of solute particles in a given amount of solvent are called colligative properties (Whitten et al., 2014). This boiling point also depend on type of chemical bonding, intermolecular forces, molecular strcture and size, phase, and crystal lattice for solid (Atkins et al., 2010; Chang, 2010; Zumdahl et al., 2020). Boiling point elevation is one concept of the colligative properties. In this concept molality (m), but not Molarity (M), is used to express the number of solutes in the solution. Differ from Molarity, molality is the number of moles of solute dissolved in 1000 grams of solvent (Chang, 2010). Therefore, in its experiment, maintaining the amount of solvent in the solution (molality) is a necessity.

In the boiling point elevation experiments the solvent is heated throughout the experiment, so that the amount of solvent may decrease at any time. A lot of publication talk about boiling point (Abaev et al., 2008; Analita et al., 2023; Andrade-Gamboa et al., 2021;

Elsayed et al., 2021; Glasser, 2023; Hartin et al., 2019; Hribar et al., 2020; Mukwembi et al., 2021; Pinarbasi et al., 2009; Šima, 2016; Wang et al., 2024; Xalikovna, 2021).

It means that the amount of solvent could not be maintain, if use inappropriate tools construction, because of the evaporation. On the other hand, the finding misconceptions of this experiments in high school (Anggun et al., 2014; Himmah et al., 2015; Prastika, 2014), and also in undergraduate students (Nurrohman, 2012). On those paper, usually used inappropriate tools construction to determine the boiling point elevation of the solvent/solution, an open container so that the water (as a solvent) vapor goes to the atmosphere. Therefore, volume of the solvent becoming decrease, its' caused concentration of the solution would be increase.

Those misconception of construction found in LabMaya also (Purwanto, 2020). LabMaya is a website published by the directorate of high schools of the Indonesian ministry of education and culture. It contains a virtual experiment of boiling point elevation. Although it is now inaccessible but the tutorial is still found on

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YouTube, and anyone can access this tutorial at anytime and anywhere. Furthermore, misconception is not only to be observed in today's children or students –even scientists and philosophers developed and lived with many misconceptions in the past (Barke et al., 2009). Historical concepts and their changes are very interesting because similar ideas can help our students today; just like early scientists did they develop their own concepts by similar observation e.g. in regard to the combustion (Barke et al., 2009). Historically, since Priestley's discovery of oxygen in 1774 oxidation used to discribes any reaction involving oxygen (combustion), but during 19th century lost of electrons or increase in oxidation number is called oxidation (Bergethon, 1998; Jenkins et al., 1996). This is proved that ideas those are developed without having any prior knowledge of the subject are not necessary false but can be described as alternative or original.

The case study we conducted on the 2nd chemistry education students, by giving a problem about the boiling point elevation, theoretically they were able to calculate the boiling point elevation well using the right equation (Chang, 2010; Silberberg, 2007; Whitten et al., 2014). They used the appropriate concentration, i.e. molality. However, they had misconceptions in designing their experiments. They used an apparatus construction in an open container (beaker), their construction of tools as precise as the references above.

Their misconceptions are strongly suspected to be due to the references they used. In addition, the books they used explain the theoretical aspect only. Even in the advance literatures do not discuss the boiling point elevation experiment (Levine, 2009; Levit, 1973). The misconceptions can be called school-made misconceptions (Barke et al., 2009). So that, one of the factors that cause this misconception is inappropriate teaching materials. Since the experiment above have fatal misconceptions, especially regarding the construction of experimental tools used in that simulation, it is necessary to address them. How to reconstruct the apparatus of the boiling point elevation experimental. This study is to overcome the lack of school-made misconceptions.

Method

There were two step testing in this research. Figure 2 provide a scheme of research. The first testing is conducted to prove the error of construction boiling point apparatus as in LabMaya (Figure 1a) compared to the real apparatus according to the LabMaya experiment. This step aims to know how many percent of error when the experiment as in LabMaya construction was carried out using the real equipment.

This is assumed that the experiment held for 100 mL of solvent on the different size of beacker (100, 150, and 200 mL) and labeled A, B, and C respectively (Figure 1b). The experiment was carried out 10 times for each variation in the volume of the Beaker, by heating 100 mL of distilled water for about 20 minutes and recording temperature changes every 10 seconds.

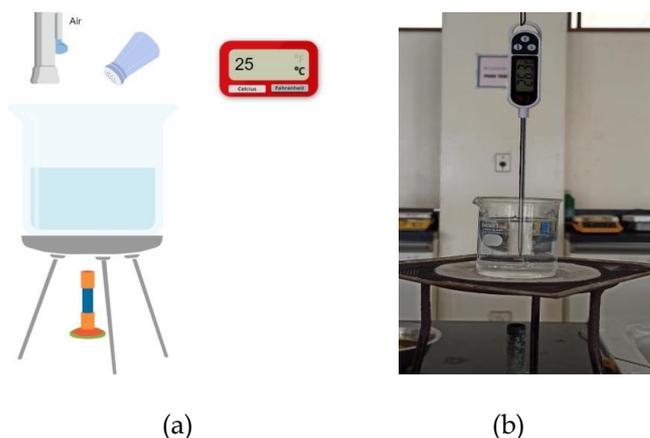


Figure 1. Construction boiling point apparatus: (a) Tools display in the LabMaya and (b) The real experiment

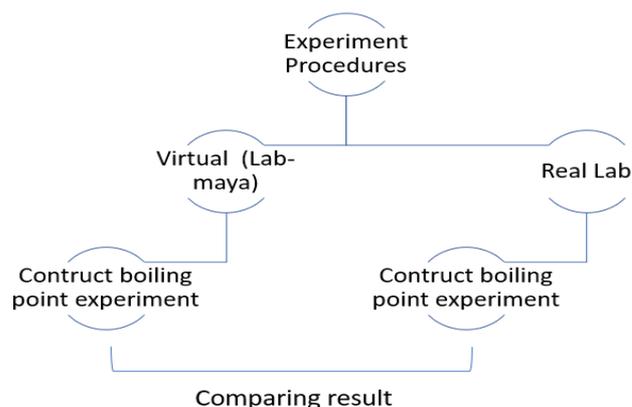


Figure 2. Scheme of research by comparing virtual and real in laboratory

Meanwhile, the 2nd step was conducted to test the reconstruction of the apparatus to overcome of the problem. The main equipment used were a two-neck flask as the container and three kind of condensers such as Vigreux, Liebig, and Graham (Figure 3a, 3b, 3c). This variation of the condenser aims to obtain the best condenser in keeping the amount of solvent. In this method, the experiment was carried out four times for each type of condenser.

Data of the first step were tested by one-way ANOVA and Tu-key's methods. ANOVA is a test Tests whether there are any statistically significant differences between the means of three or more independent (unrelated) groups, while Tukey is a post hoc test used after a significant one-way ANOVA result (Field, 2013;

Howell, 2012). Those analysis aim to find the significance of the differences in the volume variations of the beaker size. Meanwhile, data of the second step were tested by Kruskal-Wallis, to analyze the significance type of condenser used. The final stage is the t-Mann Withney test to see the difference in solvent volume reduction that occurs between the two constructions.

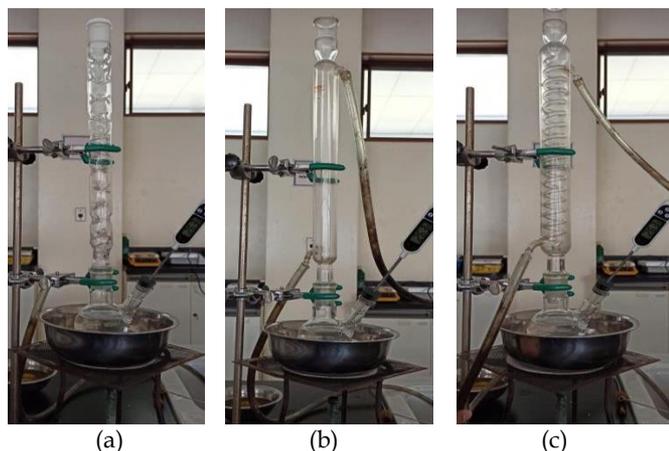


Figure 3. Tool design reconstruction with condenser variations, (a) Vigreux, (b) Liebig, and (c) Graham

Result and Discussion

In this study, the time used for heating was about 30 minutes to ensure that the distilled water has reached equilibrium, by obtaining at least 40 temperature data record at equilibrium. Data obtained is used to measure the boiling point of distilled water, as the solvent. Based on the recording of temperature changes that are carried out, a graph of temperature versus time is obtained with the following example, as in Figure 4.

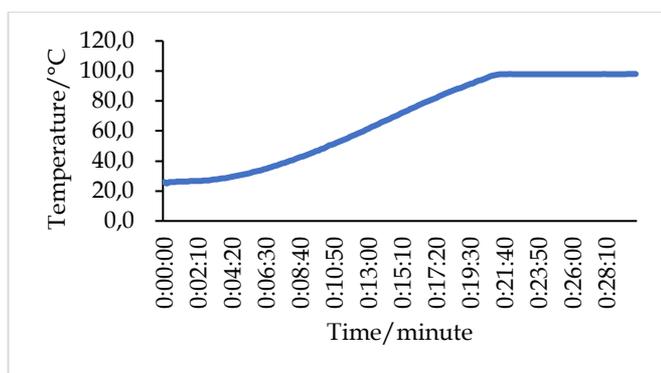


Figure 4. Temperature vs time obtained of the real experiment

Results obtained of the first step are shown in Table 1. Resulting data, the average remaining solvent in Beaker-A, B, and C is 78.35; 75.00; and 71.05 mL respectively. It means that, if we heat 100 mL of distilled

water using Beaker-A than at the boiling point volume of solvent would be 78.35 mL. In this construction, system lost 21.65 mL of solvent because the solvent vapor flows into the air during heating.

Table 1. The Remaining Volume of Solvent in Construction of LabMaya $V_i. (mL)^{-1} = 100$

Experiment	Beaker Glass		
	A	B	C
1	78.0	80.0	72.0
2	80.0	77.0	75.0
3	77.0	80.0	70.0
4	79.0	70.0	70.5
5	79.0	75.5	74.0
6	75.0	73.0	72.0
7	75.0	71.0	69.5
8	82.5	79.0	66.0
9	78.0	72.5	76.5
10	80.0	72.0	65.0
$\bar{V}_f(mL)^{-1}$	78.35	75.00	71.05

Results of the ANOVA test (Table 2) show that there is a significant difference between the uses of beakers on reducing the amount of solvent. Based on Tukey's test (Table 3), it was found that there was a significant difference between 100 mL and 150 mL beakers with 200 mL volumes. Based on trend of its mean value, it can be seen as bigger as capacity Beaker Glass is the greater reduction in volume of the solvent.

Table 2. ANOVA Test Results from Experiments Using Labmaya Tool Construction

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	267.050	2	133.525	12.007	0.000186
Within Groups	300.250	27	11.120		
Total	567.300	29			

Table 3. Tukey's Test Results from the Experiment

Beaker glass	N	1	2
A	10	71.050	
B	10		75.000
C	10		78.350

In those construction, all of the reduction in the solvent very significant in influencing the results of the boiling point test. For example, the experiment is carried out using open Beaker Glass (A, B, and C). Assume in each Beaker Glass 100 mL of solvent is used, each dissolved glucose as much as 0.01 mol, and the density of water is 1 gram/mL. By using this equation, $\Delta T_b = K_b m$ (Levine, 2009; Silberberg, 2007; Whitten et al., 2014), would have elevation of boiling point is 0.0653 °C, 0.0683 °C, and 0.0721 °C respectively. Meanwhile, the simulation result based on labMaya is 0.052 °C. So boiling point elevation of the real experiment will be

greater than LabMaya, there is a difference in results of 27.63%, 33.33%, and 40.75% respectively. These prove that the use of LabMaya's design has a great error. The larger the volume size of the Beaker Glass used, the greater the error. The changes in concentration that occur due to reduced solvent will result in boiling point elevation is not measured correctly (Brady, 2009; Eseyin et al., 2009; Levine, 2009).

In addition to the incorrect use of the container, the simulated set of tools, especially for the thermometer, also shows an illogical arrangement. As can be seen in Figure 1a, the thermometer is not connected to the liquid in the container, all that is visible is a picture of a digital thermometer separated from the container. The thermometer display should have the sensor immersed in the liquid whose temperature is being monitored. Therefore, the construction of boiling point elevation experiments on LabMaya is not recommended.

Construction of the Apparatus

Some weaknesses online practicum are: limited hands-on experience (Ali, 2020), reduced supervision and feedback (Rapanta et al., 2020), technology and connectivity issues (Dhawan, 2020), lack of personal skill advancement (Bozkurt et al., 2020), difficulty online practicum evaluation (Hodges et al., 2024), lack of professional identity formation (Adedoyin et al., 2020), reduced engagement and motivation (Bolliger et al., 2012), raising challenges related to provacy (Reamer, 2013), and time management challenges (Hung et al., 2010).

Furthermore, the misconceptions occur in the LabMaya simulation are caused by not paying attention to the construction of equipment suitable for molality. Based on a case study in my class, there were 38 students, all of whom could do problems about molarity and convert it into molality but they could not distinguish how it was used in experiments. It is important to understand the choice of concentration unit here. We are dealing with a system (the solution) whose temperature is not constant, so we can not express the concentration units in molarity because molarity changes with temperature (Chang, 2010).

Molality is a type of concentration commonly used in experiments on the colligative properties of solutions, such as the elevation of boiling point of solvents or solutions. In the experiment, the system being studied is subjected to heating so the construction of the apparatus is crucial to maintain the amount of solvent at any time. It means that a device is needed that can condense the solvent vapor into liquid and return to its container. It is commonly called a condenser.

Ideally, the Ebulliometer cell and cottrell pump would be used for this experiment, Figure 5 (Levit, 1973).

However, the availability of such equipment in the laboratory is very rare. Instead, this experiment uses a two-neck flask as a container and a condenser is connected to it. Many types of condensers can be used in these experiments, three of which are Vigreux, Liebig, and Graham. To ensure that the generated vapor returns to its container, the condenser is mounted vertically as seen in Figure 2.

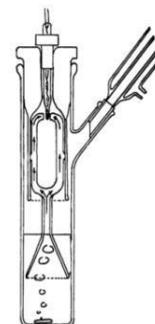


Figure 5. Ebulliometer cell and cottrell pump

The data obtained of each tool reconstruction can be seen in Table 4. The analysis of the effect of kind of condensers was tested using the Kruskal-Wallis test (Table 5) because the data obtained did not meet the normality limit on $p > 0.05$. Results of the test showed that there was not significant difference between the three condenser uses. It means that all the construction can be used in this experiment. However, based on the mean rank, it can be received that the sequence of condensers that are better at keeping the amount of solvent constant such as Graham, Liebig, and Vigreux, respectively. It can be seen that the use of a Braham condenser can maintain a constant amount of solvent, and better than another. So, it can be concluded that the Graham condenser is the most appropriate for use in the elevation of boiling point experiment. The condensor itself in boiling point experiment have several function, they are: It turns the vapour into liquid so as to avoid losing some volatile substances; helps keep the system's pressure level and temperature constant, allowing precision calculation for boiling point; and prevents flammable or toxic gases from being emitted it makes things safer (Pavia et al., 2014).

Table 4. Data on the Remaining Volume (mL) of Solvent in the Experiment Using Reconstruction Tool

Experiment	Condensor		
	Vigreux (mL)	Liebeg (mL)	Graham (mL)
1	99.0	99.5	100.0
2	95.0	100.0	100.0
3	96.0	99.5	100.0
4	100.0	100.0	100.0
$\bar{V}_f(mL)^{-1}$	97.5	99.75	100.0

Table 5. The Kruskal-Wallis Test Results from the Experiment Using Reconstruction

Condensor	N	Mean Rank		Volume
Graham	4	9.00	Kruskal-Wallis	5.332
Liebig	4	6.75	df	2
Vigreux	4	3.75	Asymp. Sig.	0.070
Total	12			

The analysis to test of differences in the result of LabMaya's equipment construction with the reconstructed tools was carried out using the Mann-Whitney non-parametric method. Based on the results of the t-mann whitney test (Table 6 and 7) it was found that the significance value was 0.004. So that it can be concluded that there is a significant difference between the use of LabMaya's equipment and the reconstruction apparatus, with the error less than 5%.

Table 6. Mann-Whitney Test Results

Tool Construction	N	Mean Rank	Sum of Ranks
Beaker*	10	5.50	55.00
Graham	4	12.50	50.00
Total	14		

Note: *100 mL

Table 7. Test Statistics^a

Mann-Whitney U	0.000
Wilcoxon	55.000
Z	-2.873
Asymp. Sig. (2-tailed)	0.004
Exact Sig. [2*(1-tailed Sig.)]	0.002b

The difference in the percentage of errors that occur between LabMaya's construction and the reconstruction results is due to the amount of solvent. In the construction of LabMaya and another experiment (Anggun et al., 2014; Himmah et al., 2015; Nurrohman, 2012; Prastika, 2014), the vapor does not return back to the container so that the volume continues to decrease over time. This construction does not match the requirements for this type of molality concentration in actual experiments. Developing a virtual laboratory, there are several requirements that must be met, one of them is crucial which is using the real authentic devices or tools (Potkonjak et al., 2016).

On the other hand, the reconstruction equipment used in real experiments has very small errors. This is due to the use of condensers, such as the Vigreux and Liebig, and even the device using the Graham condenser has no error. Those are because the vapor that occurs returns to its container, so there is no loss of solvent. Assessing the correctness of the tools and its operating unctions and works is one of the steps on developing virtual laboratory or experimental simulation (Palagin et al., 2007). So that, this simulation that use the

reconstruction apparatus will represent the real experiment of the boiling point elevation as it is intended to be preparatory, supplement or even alternative replacement of hand-on experiment when it is unable to be done (de las Heras et al., 2021). Therefore, this reconstruction device is very suitable for use in the boiling point elevation experiment.

Conclusion

The construction of the apparatus used in boiling point elevation experiments is an important aspect. Therefore, a reconstruction of the experimental apparatus has been carried out to obtain a function similar to the Cottrel Brown Boiling Point Apparatus. LabMaya tool construction has a very large error, using different size beaker glass there are differences in results of 27.63%, 33.33%, and 40.75%. So, the construction of LabMaya is not recommended in this experiment. Instead, the reconstructed apparatus in this study, using a two-neck flask connected to a condenser, proved to be able to maintain the amount of solvent so that it did not change the concentration of solution. The reconstruction equipment used in real experiments has a very small error, less than 5%, due to the use of condensers. Of the three condensers used, Vigreux, Liebig, and Graham, it was found that Graham's condenser had the best accuracy. So that it is recommended to use in the virtual lab experiment.

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Conflicts of Interest

The authors declare no conflict of interest.

References

- Abaev, G. N., Dubrovskii, A. V., & Abaev, R. G. (2008). Determination of the initial boiling point and end point of petroleum products in minidistillation. *Chemistry and Technology of Fuels and Oils*, 44(1), 55–60. <https://doi.org/10.1007/s10553-008-0005-6>
- Adedoyin, O. B., & Soykan, E. (2020). Covid-19 pandemic and online learning : the challenges and opportunities. *Interactive Learning Environments*,

- 0(0), 1–13.
<https://doi.org/10.1080/10494820.2020.1813180>
- Ali, W. (2020). Online and Remote Learning in Higher Education Institutes: A Necessity in light of COVID-19 Pandemic. *Higher Education Studies*, 10(3), 16. <https://doi.org/10.5539/hes.v10n3p16>
- Analita, R. N., Bakti, I., Nugraheni, P. W., & Noviyanti, E. (2023). The learners' conceptual understanding: Literature review of vapor-pressure lowering and boiling-point elevation. *Journal of Education and Learning (EduLearn)*, 17(4), 641–651. <https://doi.org/10.11591/edulearn.v17i4.20805>
- Andrade-Gamboa, J., & Donati, E. R. (2021). Does taper water boil at all temperatures? *Educación Química*, 32(2), 143. <https://doi.org/10.22201/fq.18708404e.2021.2.76225>
- Anggun, E., Hutami, R., & Sekartaji, S. R. (2014). *Laporan Kenaikan Titik Didih dan Penurunan Titik Beku*. Bekasi: SMA 4 Tambun Selatan.
- Atkins, P., & Jones, L. (2010). *Chemical Principles: The Quest for Insight* (5th ed.). W.H. Freeman.
- Barke, H. D. A.-H., & Yitbarek. (2009). *Misconceptions in Chemistry: Addressing Perceptions in Chemistry Education*. Verlag Berlin Heidelberg: Springer.
- Bergethon, P. R. (1998). Chemical Principles. In *The Physical Basis of Biochemistry* (fourth, pp. 158–172). New York: Springer. https://doi.org/10.1007/978-1-4757-2963-4_10
- Bolliger, D. U., & Halupa, C. (2012). Student perceptions of satisfaction and anxiety in an online doctoral program. *Distance Education*, 33(1), 81–98. <https://doi.org/10.1080/01587919.2012.667961>
- Bozkurt, A., & Sharma, R. (2020). Emergency remote teaching in a time of global crisis due to CoronaVirus pandemic. *Asian Journal of Distance Education*, 15(1), 1–6. <https://doi.org/10.5281/zenodo.3778083>.
- Brady, J. E. (2009). *Chemistry: matter and its changes*. United States of America: John Wiley & Sons, Inc.
- Chang, R. (2010). *Chemistry* (10th ed.). New York: McGraw-Hill.
- de las Heras, S. C., Kensington-Miller, B., Young, B., Gonzalez, V., Krühne, U., Mansouri, S. S., & Baroutian, S. (2021). Benefits and Challenges of a Virtual Laboratory in Chemical and Biochemical Engineering: Students' Experiences in Fermentation. *Journal of Chemical Education*, 98(3), 866–875. <https://doi.org/10.1021/acs.jchemed.0c01227>
- Dhawan, S. (2020). Online Learning: A Panacea in the Time of COVID-19 Crisis. *Journal of Educational Technology Systems*, 49(1), 5–22. <https://doi.org/10.1177/0047239520934018>
- Elsayed, M. L., Wu, W., & Chow, L. C. (2021). High salinity seawater boiling point elevation: Experimental verification. *Desalination*, 504, 114955. <https://doi.org/10.1016/j.desal.2021.114955>
- Eseyin, A. E., Steele, P. H., Chang, R., & Soewarno, N. (2009). *Chemistry* (Tenth). McGraw-Hill.
- Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics* (4th ed.). Sage Publications.
- Glasser, L. (2023). Thermal stability of ionic solids: A boiling points survey. *Chemical Thermodynamics and Thermal Analysis*, 10, 100114. <https://doi.org/10.1016/j.ctta.2023.100114>
- Hartin, A., Ringwald, A., & Tapia, N. (2019). Measuring the boiling point of the vacuum of quantum electrodynamics. *Physical Review D*, 99(3), 036008. <https://doi.org/10.1103/PhysRevD.99.036008>
- Himmah, F., Yuni, R., Nihwan, M. T., Nadiya, D., & Ainun, W. N. (2015). Kenaikan Titik Didih. In *Laporan Praktikum Larutan*. Prodi S1-Pendidikan IPA FMIPA Universitas Negeri Surabaya. Retrieved from https://www.academia.edu/19646613/LAPORA_N_PRAKTIKUM_Kenaikan_titik_didih
- Hodges, C. B., Moore, S., Lockee, B. B., Trust, T., & Bond, M. A. (2024). The Difference between Emergency Remote Teaching and Online Learning. In *Handbook of Research in Online Learning* (pp. 511–522). BRILL. https://doi.org/10.1163/9789004702813_021
- Howell, D. C. (2012). *Statistical Methods for Psychology* (8th ed.). Cengage Learning.
- Hribar, J., & Donlagic, D. (2020). Fiber-Optic Boiling Point Sensor for Characterization of Liquids. *IEEE Sensors Journal*, 20(14), 7731–7739. <https://doi.org/10.1109/JSEN.2020.2982420>
- Hung, M. L., Chou, C., Chen, C. H., & Own, Z. Y. (2010). Learner readiness for online learning: Scale development and student perceptions. *Computers and Education*, 55(3), 1080–1090. <https://doi.org/10.1016/j.compedu.2010.05.004>
- Jenkins, F., Kessel, H., Tompkins, D., & Lantz, O. (1996). *Chemistry*. Canada: International Thomson Publishing.
- Levine, I. N. (2009). *Physical Chemistry* (6th ed.). New York: McGraw-Hill.
- Levit, B. P. (1973). *Findlay's Practical Physical Chemistry*. New York: Longman Group Limited.
- Mukwembi, S., & Nyabadza, F. (2021). A new model for predicting boiling points of alkanes. *Scientific Reports*, 11(1), 24261. <https://doi.org/10.1038/s41598-021-03541-z>
- Nurrohman, M. R. (2012). *Alat Peraga Kimia Penentu Kenaikan Titik Didih (Boiling Point Elevation)*

- Berbahan Dasar Seng Sebagai Media Pembelajaran Dalam Praktikum Kimia Di Ma/Sma Kelas Xii.* UIN Sunan Kalijaga. Retrieved from <https://digilib.uin-suka.ac.id/id/eprint/8098/>
- Palagin, O., Romanov, V., Sachenko, A., Galelyuka, I., Hrusha, V., Kachanovska, M., & Kochan, R. (2007). Virtual laboratory for computer-aided design: Typical virtual laboratory structure and principles of its operation. In *2007 4th IEEE Workshop on Intelligent Data Acquisition and Advanced Computing Systems: Technology and Applications, IDAACS* (pp. 77–81). IEEE. <https://doi.org/10.1109/IDAACS.2007.4488378>
- Pavia, D. L., Lampman, G. M., Kriz, G. S., & Engel, R. G. (2014). *Introduction to Organic Laboratory Techniques: A Microscale Approach* (5th ed.). Cengage Learning.
- Pinarbasi, T., Sozbilir, M., & Canpolat, N. (2009). Prospective chemistry teachers' misconceptions about colligative properties: boiling point elevation and freezing point depression. *Chem. Educ. Res. Pract.*, *10*(4), 273–280. <https://doi.org/10.1039/B920832C>
- Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrović, V. M., & Jovanović, K. (2016). Virtual laboratories for education in science, technology, and engineering: A review. *Computers & Education*, *95*, 309–327. <https://doi.org/10.1016/j.compedu.2016.02.002>
- Prastika, H. H. (2014). *Laporan Praktikum Titik Leleh dan Titik Didih.* FMIPA Universitas Udayana. Retrieved from https://www.academia.edu/73889193/Laporan_Praktikum_Kimia_Organik_I_Destilasi_dan_Titik_Didih
- Purwanto, A. da. M. (2020). *Praktikum Maya untuk Mendukung Pembelajaran Jarak Jauh di SMA.* Jakarta: Kemendikbud.
- Rapanta, C., Botturi, L., Goodyear, P., Guàrdia, L., & Koole, M. (2020). Online University Teaching During and After the Covid-19 Crisis: Refocusing Teacher Presence and Learning Activity. *Postdigital Science and Education*, *2*(3), 923–945. <https://doi.org/10.1007/s42438-020-00155-y>
- Reamer, F. G. (2013). Social Work in a Digital Age: Ethical and Risk Management Challenges. *Social Work*, *58*(2), 163–172. <https://doi.org/10.1093/sw/swt003>
- Silberberg, M. S. (2007). *Principles of General Chemistry.* New York: McGraw-Hill.
- Šima, J. (2016). Structure-related melting and boiling points of inorganic compounds. *Foundations of Chemistry*, *18*(1), 67–79. <https://doi.org/10.1007/s10698-015-9228-x>
- Wang, B., Shen, S., & Mu, X. (2024). Exploring the boiling point elevation of multicomponent salt solution by changing vapor pressure and solution composition. *Applied Thermal Engineering*, *253*, 123722. <https://doi.org/10.1016/j.applthermaleng.2024.123722>
- Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2014). *Chemistry* (3th ed.). Belmont-USA: Mary Finch.
- Xalikovna, M. R. (2021). Experimental Determination Of The Boiling Point Of Tomato Paste. *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, *12*(13), 1700–1704. <https://doi.org/10.17762/turcomat.v12i13.8798>
- Zumdahl, S. S., & Zumdahl, S. A. (2020). *Chemistry: An Atoms First Approach* (3rd ed.). Cengage Learning.