

**PERKULIAHAN KIMIA KOORDINASI DENGAN PRINSIP  
*SUSTAINABILITY OF THE MOLECULAR LEVEL* UNTUK  
MENINGKATKAN BERPIKIR SISTEM MAHASISWA**

**DISERTASI**

**Diajukan untuk Memenuhi Sebagian Syarat untuk Memperoleh  
Gelar Doktor Pendidikan Ilmu Pengetahuan Alam**



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# **PERKULIAHAN KIMIA KOORDINASI DENGAN PRINSIP *SUSTAINABILITY OF THE MOLECULAR* LEVEL UNTUK MENINGKATKAN BERPIKIR SISTEM MAHASISWA**

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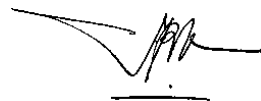
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**ABSTRAK**

Penelitian ini bertujuan untuk menghasilkan desain program perkuliahan kimia koordinasi dengan prinsip *sustainability of the molecular level* untuk meningkatkan berpikir sistem mahasiswa. Desain penelitian yang digunakan yaitu *mix methods* tipe *exploratory design* dengan menggunakan kerangka berpikir *Model*. Partisipan dalam penelitian ini berjumlah lima puluh mahasiswa pendidikan kimia pada salah satu LPTK di Kabupaten Cirebon. Instrumen penelitian yang digunakan terdiri atas pedoman wawancara prakonsepsi mahasiswa, format untuk analisis konten konsepsi ilmuwan, rancangan desain tahapan pembelajaran yang dikembangkan, tes berpikir sistem, peta konsep berorientasi sistem. Teknik analisis data menggunakan *qualitative content analysis* (QCA), statistik deskriptif, N-Gain, *Gain Score*, uji *mann whitney*. Hasil penelitian menunjukkan bahwa 1) desain tahapan yang dikembangkan terdiri dari tujuh tahapan dengan konten yang diajarkan berdasarkan hasil analisis konsepsi ilmiah terhadap delapan literatur dan hasil wawancara prakonsepsi terhadap dua puluh lima mahasiswa mengenai topik senyawa kompleks koordinasi logam tanah jarang. Rancangan desain tahapan pembelajaran diimplementasikan kepada 50 mahasiswa Program Pendidikan Kimia. 2) Skor rata-rata N-gain sebesar 0,26 menunjukkan adanya peningkatan dengan kategori rendah pada keterampilan berpikir sistem mahasiswa pada capaian rata-rata pretes dan postes setelah mengikuti perkuliahan. 3) profil berpikir sistem mahasiswa ditunjukkan pada perubahan dalam cara mahasiswa memandang dan memproses informasi, serta kemampuan mahasiswa mengaitkan konsep-konsep dalam suatu kerangka sistematis. Berdasarkan peta konsep yang dibuat mahasiswa, terdapat total 1208 konsep yang dikaitkan hingga membentuk suatu kerangka yang sistematis. Hal ini mengindikasikan bahwa mahasiswa telah mampu mengembangkan kemampuan berpikir sistematis, kritis dalam menganalisa konsep kimia koordinasi serta aspek keberlanjutan pada tingkat molekuler.

Kata kunci: Desain tahapan pembelajaran, *Model of Educational Reconstruction* (MER), *Sustainability of the molecular level*, Berpikir sistem.

**COORDINATION CHEMISTRY LECTURES BASED ON  
SUSTAINABILITY OF THE MOLECULAR LEVEL PRINCIPLES TO  
IMPROVE STUDENTS' SYSTEMS THINKING**

**ABSTRACT**

This research aims to produce a complex chemistry lecture program design in coordination with the principles of the sustainability of the molecular level to improve students' systems thinking. The research design used is a mix methods type exploratory design using a model thinking framework. Participants in this research were fifty chemistry education students at one of the LPTKs in Cirebon Regency. The research instruments used consisted of student preconception interview guidelines, formats for content analysis of scientists' conceptions, designs for the learning stages developed, systems thinking tests, system-oriented concept maps. Data analysis techniques use qualitative content analysis (QCA), descriptive statistics, N-Gain, Gain Score, Mann Whitney test. The research results show that 1) the stage design developed consists of seven stages with the content taught based on the results of scientific conception analysis of eight pieces of literature and the results of preconception interviews with twenty-five students regarding the topic of rare earth metal coordination complex compounds. The design of the learning stages was implemented on 50 prospective chemistry teacher students. 2) The average N-gain score of 0.26 shows an increase in the low category in students' systems thinking skills in the average pre-test and post-test achievements after attending the lecture. 3) A student's system thinking profile can be shown in changes in the way students perceive and process information, as well as the student's ability to link concepts in a systematic framework. Based on the concept map created by students, there are a total of 1208 concepts that are linked to form a systematic framework. This indicates that students have been able to develop systematic and critical thinking skills in analyzing coordination chemistry concepts and sustainability aspects at the molecular level.

Keywords: Design of learning sequence, Model of Educational Reconstruction (MER), Sustainability of the molecular level, Systems thinking.

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## DAFTAR PUSTAKA

- Adeyemi, I., Abu-Zahra, M. R. M., & AlNashef, I. M. (2018). Physicochemical properties of alkanolamine-choline chloride deep eutectic solvents: Measurements, group contribution and artificial intelligence prediction techniques. *Journal of Molecular Liquids*, 256(2017), 581–590. <https://doi.org/10.1016/j.molliq.2018.02.085>.
- Akash, M. S. H., Rehman, K., Akash, M. S. H., dan Rehman, K. (2020). Differential scanning calorimetry. *Essentials of pharmaceutical analysis*, 199-206.
- Almustafa, G., Sulaiman, R., Kumar, M., Adeyemi, I., Arafat, H. A., AlNashef, I., Chen, W., Li, X. X., Chen, L., Zhou, G., Lu, Q., Huang, Y., Chao, Y., Zhu, W., Hua, Y., Sun, Y., Yan, F., Wang, S., Xu, Z., ... Binnemans, K. (2021). Cyclodextrin-based deep eutectic solvents for efficient extractive and oxidative desulfurization under room temperature. *Chemical Engineering Journal*, 117(February), 10715–10722. <https://doi.org/10.1016/j.cej.2022.136022> <https://doi.org/10.1016/j.cej.2021.129249> <http://xlink.rsc.org/?DOI=C5TC02043C> <https://doi.org/10.1016/j.cej.2021.133200> <https://doi.org/10.1016/j.cej.2020.127648> <https://doi.org/10.1016/j.cej.2020.12517>
- Anastas, P. T., Heine, L. G., & Williamson, T. C. (2000). Green Chemical Syntheses and Processes: Introduction. 1–6. <https://doi.org/10.1021/bk-2000-0767.ch001>
- Anastas, P. T. Kirchoff, M. M. (2002). Origins currents status and future challenges of green chemistry\_AccChemRes\_2002.pdf. *Accounts of Chemical Research*, 35(9), 686–694.
- Anastas, P. T., & Eghbali, N. (2010). Green Chemistry: Principles and Practice. *Chemical Society Reviews*, 39(1), 301–312. <https://doi.org/10.1039/b918763b>
- Anastas, P. T., & Zimmerman, J. B. (2016). The Sustainability of the molecular level. *Chem*, 1(1), 10–12. <https://doi.org/10.1016/j.chempr.2016.06.016>
- Assaraf, O. B. Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching*, 42(5), 518–560. <https://doi.org/10.1002/tea.20061>
- Assaraf, O. B. Z., & Orion, N. (2010). System thinking skills at the elementary school level. *Journal of Research in Science Teaching*, 47(5), 540–563. <https://doi.org/10.1002/tea.20351>

- Atwood, D. A. (Ed.). (2013). *The rare earth elements: fundamentals and applications*. John Wiley & Sons.
- Aubrecht, K. B., Bourgeois, M., Brush, E. J., Mackellar, J., & Wissinger, J. E. (2019). Integrating Green Chemistry in the Curriculum: Building Student Skills in Systems Thinking, Safety, and Sustainability. *Journal of Chemical Education*, 96(12), 2872–2880. <https://doi.org/10.1021/acs.jchemed.9b00354>.
- Aubrecht, K. B., Dori, Y. J., Holme, T. A., Lavi, R., Matlin, S. A., Orgill, M., & Skaza-Acosta, H. (2019). Graphical Tools for Conceptualizing Systems Thinking in Chemistry Education. *Journal of Chemical Education*, 96(12), 2888–2900. <https://doi.org/10.1021/acs.jchemed.9b00314>
- Barth, M. (2014). Implementing sustainability in higher education: Learning in an age of transformation. 1-201. <https://doi.org/10.4324/9780203488355>.
- Battle, Michele., Fisher. (2015). *Application of Systems Thinking to Health Policy & Public Health Ethics : Public Health and Private illness*. 2015th Edition. Springer Publisher.
- Batzri, O., Ben Zvi Assaraf, O., Cohen, C., & Orion, N. (2015). Understanding the earth systems: Expressions of dynamic and cyclic thinking among university students. *Journal of Science Education and Technology*, 24(6), 761–775. <https://doi.org/10.1007/s10956-015-9562-8>
- Bhatt, V. (2015). Essentials of Coordination Chemistry: A Simplified Approach with 3D Visuals. In *Essentials of Coordination Chemistry: A Simplified Approach with 3D Visuals*. <https://doi.org/10.1016/C2014-0-04361-4>
- Binnemans, C. Gçrller-Walrand, J. *Rare Earths* (1996), 14, 173 – 180.
- Binnemans, J. *Phys. Chem. B* (2006), 110, 20978 – 20992.
- Binnemans, K., Jones, P. T., Blanpain, B., Van Gerven, T., & Pontikes, Y. (2015). Towards zero-waste valorisation of rare-earth-containing industrial process residues: a critical review. *Journal of Cleaner Production*, 99, 17-38.
- Boersma, K., Goedhart, M., De Jong, O., & Eijkelhof, H. (2005). Research and the quality of science education. In *Research and the Quality of Science Education*. <https://doi.org/10.1007/1-4020-3673-6>
- Borra, C. R., Pontikes, Y., Binnemans, K., & Van Gerven, T. (2015). Leaching of rare earths from bauxite residue (red mud). *Minerals engineering*, 76, 20-27.
- Böschen, S., Lenoir, D., & Scheringer, M. (2003). Sustainable chemistry: starting points and prospects. *Naturwissenschaften*, 90, 93-102.

- Burmeister, M., & Eilks, I. (2012). *Development of a Training Module for Future Chemistry Teachers on Development of a Training Module for Future Chemistry Teachers on Education for Sustainable Development*. July, University Bremen, Germany, 62–67.
- Burmeister, M., Rauch, F., & Eilks, I. (2012). Education for Sustainable Development (ESD) and chemistry education. *Chemistry Education Research and Practice*, 13(2), 59–68. <https://doi.org/10.1039/c1rp90060a>
- Burmeister, M., Schmidt-Jacob, S., & Eilks, I. (2013). German chemistry teachers' understanding of sustainability and education for sustainable development - An interview case study. *Chemistry Education Research and Practice*, 14(2), 169–176. <https://doi.org/10.1039/c2rp20137b>
- Chen, Y. C., Wilson, K., & Lin, H. S. (2019). Identifying the challenging characteristics of systems thinking encountered by undergraduate students in chemistry problem-solving of gas laws. *Chemistry Education Research and Practice*, 20(3), 594-605.
- Clark, W. C., & Dickson, N. M. (2003). Sustainability science: The emerging research program. *Proceedings of the National Academy of Sciences of the United States of America*, 100(14), 8059–8061. <https://doi.org/10.1073/pnas.1231333100>
- Coll, R. K., Gilbert, J. K., Pilot, A., & Streller, S. (2013). How to benefit from the informal and interdisciplinary dimension of chemistry in teaching. In I. Eilks & A. Hofstein (Eds.), *Teaching chemistry—a studybook. A practical guide and textbook for student teachers, teacher trainees and teachers* (pp. 241–268). Rotterdam: Sense.
- Coletta, V. P., & Steinert, J. J. (2020). Why normalized gain should continue to be used in analyzing preinstruction and postinstruction scores on concept inventories. *Physical Review Physics Education Research*, 16(1), 010108.
- Creswell, J. W., & Clark, V. P. (2011). *Mixed methods research*. SAGE Publications.
- Dhukaram, A. V., Sgouropoulou, C., Feldman, G., & Amini, A. (2018). Higher education provision using systems thinking approach—case studies. *European Journal of Engineering Education*, 43(1), 3-25.
- Duit, R., Gropengießer, H., Kattmann, U., Komorek, M., & Parchmann, I. (2012). The model of educational reconstruction - a framework for improving teaching and learning science. *Science Education Research and Practice in Europe: Retrospective and Prospective*, 13–37. <https://doi.org/10.1007/978-94-6091-900-8>.

- Eilks, I. (2015). Science education and education for sustainable development - justifications, models, practices and perspectives. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(1), 149–158. <https://doi.org/10.12973/eurasia.2015.1313a>.
- Fanta, Daniela.,Braeutigam,J.,Riess,W. (2019). Fostering Systems Thinking in Student Teachers of Biology and Geography- an Intervention Study. *Journal of Biological Education*. ISSN: 0021-9266 (Online), 2157-6009 (Print), DOI :10.1080/00219266.2019.1569083.
- Feinstein, N. W., & Kirchgasser, K. L. (2015). Sustainability in Science Education? How the Next Generation Science Standards Approach Sustainability, and Why It Matters. *Science Education*, 99(1), 121–144. <https://doi.org/10.1002/sce.21137>.
- Feng, X., Zhang, H., and Yu, P. (2021). X-ray fluorescence application in food, feed, and agricultural science: a critical review. *Critical reviews in food science and nutrition*, 61(14), 2340-2350.
- Firman, H. (2006). Sains-Lingkungan-Teknologi-Masyarakat Dalam Konteks Implementasi Pendidikan Untuk Pembangunan Berkelanjutan (p.9).
- Firmansyah, M. L., Kubota, F., & Goto, M. (2018). Solvent extraction of Pt (IV), Pd (II), and Rh (III) with the ionic liquid trioctyl (dodecyl) phosphonium chloride. *Journal of Chemical Technology & Biotechnology*, 93(6), 1714-1721.
- Flanders, N. A. (1966). *Interaction Analysis in the Classroom: A Manual for Observers*. School of Education, University of Michigan. [https://books.google.co.id/books/about/Interaction\\_Analysis\\_in\\_the\\_Classroom.html?id=nm4XnQEACAAJ&redir\\_esc=y](https://books.google.co.id/books/about/Interaction_Analysis_in_the_Classroom.html?id=nm4XnQEACAAJ&redir_esc=y).
- Guisasola, J., Zuza, K., Ametller, J., & Gutierrez-Berraondo, J. (2017). Evaluating and redesigning teaching learning sequences at the introductory physics level. *Physical Review Physics Education Research*, 13(2), 020139.
- Gupta, C. K., & Krishnamurthy, N. (1992). Extractive metallurgy of rare earths. *International materials reviews*, 37(1), 197-248.
- Gupta, C.K. (2003). *Chemical Metallurgy*. Wiley-VCH Verlag GmbH & Co. KGaA Weinheim, The Federal Republic of Germany.
- Gurel, D. K., Eryilmaz, A., & McDermott, L. C. (2015). A review and comparison of diagnostic instruments to identify students' misconceptions in science. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(5), 989–1008. <https://doi.org/10.12973/eurasia.2015.1369a>.



- Hagiwara, R., & Ito, Y. (2000). Room temperature ionic liquids of alkylimidazolium cations and fluoroanions. *Journal of Fluorine Chemistry*, 105(2), 221-227.
- Hakim, L. N. (2013). Ulasan Metodologi Kualitatif: Wawancara Terhadap Elit. Aspirasi, 4(2), 165–172. <https://jurnal.dpr.go.id/index.php/aspirasi/article/view/501>.
- Hansen, B. B., Spittle, S., Chen, B., Poe, D., Zhang, Y., Klein, J. M., Horton, A., Adhikari, L., Zelovich, T., Doherty, B. W., Gurkan, B., Maginn, E. J., Ragauskas, A., Dadmun, M., Zawodzinski, T. A., Baker, G. A., Tuckerman, M. E., Savinell, R. F., & Sangoro, J. R. (2021). Deep Eutectic Solvents: A Review of Fundamentals and Applications. *Chemical Reviews*, 121(3), 1232–1285. <https://doi.org/10.1021/acs.chemrev.0c00385>.
- Hendriawan, D., & Asriah Maulia, L. N. (2020). Integrated Teaching Material with Education for Sustainable Development on History Subject for High Schools Curriculum Development. *Journal of Physics: Conference Series*, 1477(4). <https://doi.org/10.1088/1742-6596/1477/4/042030>.
- Henshaw, J. L. (2019). Systems thinking for systems making: Joining systems of thought and action. *Systemic practice and action research*, 32(1), 63-91.
- Hernández, M. I., Couso, D., & Pintó, R. (2015). Analyzing students' learning progressions throughout a teaching sequence on acoustic properties of materials with a model-based inquiry approach. *Journal of Science Education and Technology*, 24, 356-377.
- Hernani, H., Mudzakir, A., & Sumarna, O. (2016). Ionic Liquids Material as Modern Context of Chemistry in School. *Jurnal Pendidikan IPA Indonesia*, 5(1), 63-68.
- Herron, J. D. (2005). Introduction to chemists' guide to effective teaching. In N. J. Pienta, M. M. Cooper, & T. J. Greenbowe (Eds.), *Chemists' guide to effective teaching* (Vol. 1, pp. 2–11). Upper Saddle River, NJ: Pearson Education.
- Hodson, D. (2013). Don't be nervous, don't be flustered, don't be scared. Be prepared. *Canadian Journal of Science, Mathematics and Technology Education*, 13, 313-331.
- Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: Making chemistry studies more relevant. *International Journal of Science Education*, 28(9), 1017–1039. doi:10.1080/09500690600702504.
- Holbrook, J. (2005). Making chemistry teaching relevant. *Chemical education international*, 6(1), 1-12.

- Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29(11), 1347–1362. <https://doi.org/10.1080/09500690601007549>
- Holme, Thomas. (2019). Systems Thinking as a Vehicle to Introduce Additional Computational Thinking Skills in General Chemistry. American Chemical Society publications.
- Hong, J. C., Chen, M. Y., & Hwang, M. Y. (2013). Vitalizing creative learning in science and technology through an extracurricular club: A perspective based on activity theory. *Thinking Skills and Creativity*, 8(1), 45–55. <https://doi.org/10.1016/j.tsc.2012.06.001>.
- Hrin, T. N., Milenković, D. D., Segedinac, M. D., & Horvat, S. (2017). Systems thinking in chemistry classroom: The influence of systemic synthesis questions on its development and assessment. *Thinking Skills and Creativity*, 23, 175–187. <https://doi.org/10.1016/j.tsc.2017.01.003>.
- [https://id.wikipedia.org/wiki/Berkas:Kelimpahan\\_unsur.svg](https://id.wikipedia.org/wiki/Berkas:Kelimpahan_unsur.svg).
- <https://iuk.ktn-uk.org/news/solutions-for-recycling-and-re-use-of-crts-deadline-extended/>).
- <https://www.nobelprize.org/prizes/chemistry/1913/summary/> (nobel prize werner).
- <https://www.unep.org/>
- Huang, C. (2010). Rare Earth Coordination Chemistry: Fundamentals and Applications. In *Rare Earth Coordination Chemistry: Fundamentals and Applications*. <https://doi.org/10.1002/9780470824870>.
- Hursini, J., Parajó, J. J., Villanueva, M., Rodríguez, J. R., Cabeza, O., and Varela, L. M. (2019). Liquid range of ionic liquid–Metal salt mixtures for electrochemical applications. *The Journal of Chemical Thermodynamics*, 134, 164-174.
- Husraini, L., Zahrina, I., and Sunarno, S. (2020). Aplikasi Deep Eutectic Solvents (DESs) Sebagai Katalis Pada Sintesis Emulsifier. *Jurnal Online Mahasiswa (JOM) Bidang Teknik dan Sains*, 7, 1-8.
- Ilankoon, I. M. S. K., Ghorbani, Y., Chong, M. N., Herath, G., Moyo, T., & Petersen, J. (2018). E-waste in the international context – A review of trade flows, regulations, hazards, waste management strategies and technologies for value recovery. *Waste Management*, 82, 258–275. <https://doi.org/10.1016/j.wasman.2018.10.018>

- Isambert, N., Duque, M. D. M. S., Plaquevent, J. C., Genisson, Y., Rodriguez, J., & Constantieux, T. (2011). Multicomponent reactions and ionic liquids: a perfect synergy for eco-compatible heterocyclic synthesis. *Chemical Society Reviews*, 40(3), 1347-1357.
- Jacobson M. J. and Wilensky U., (2006), Complex systems in education: Scientific and educational importance and implications for the learning sciences, *J. Learn. Sci.*, 15, 11–34.
- Jegstad, K. M., & Sinnes, A. T. (2015). Chemistry Teaching for the Future: A model for secondary chemistry education for sustainable development. *International Journal of Science Education*, 37(4), 655–683. <https://doi.org/10.1080/09500693.2014.1003988>.
- Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, 7, 75–83. doi:10.1111/j.1365-2729.1991.tb00230.x.
- Jones, P., & Evans, J. (2013). *Urban regeneration in the UK: Boom, bust and recovery*. Sage.
- Juntunen, M. K., & Aksela, M. K. (2014). Education for sustainable development in chemistry—challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice*, 15(4), 488-500.
- Katehi, L. (2009). *Committee on K–12 Engineering Education* Linda Katehi, Greg Pearson, and Michael Feder, Editors.
- Kates, R. W., Clark, W. C., Corell, R., Michael Hall, J., Jaeger, C. C., Lower, I., McCarthy, J. J., Joachim Schellnhuber, H., Bolin, B., Dickson, N. M., Faucheux, S., Gallopin, G. C., Grubler, A., Huntley, B., Jill, J., Jodha, N. S., Kasperson, R. E., Mabohunje, A., Matson, P., ... Svedin, U. (2001). Sustainability Science. *Science Compass*, 292(5517), 641–642.
- Kattmann, U., Duit, R., Gropengießer, H., & Komorek, M. (1996). Educational Reconstruction – Bringing Together Issues of Scientific Clarification and Students’ Conceptions. *Annual Meeting of the National Association of Research in Science Teaching (NARST)*, 1992, 19.
- Kisworo, B., Mudzakir, A., & Liliyasi, S. (2021). How does chemistry of rare earth metals coordination complexes can enhance system thinking ability? A qualitative content analysis study. *Moroccan Journal of Chemistry*, 9(2), 9-2.
- Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*,

85(3), 291–310. <https://doi.org/10.1002/sce.1011>.

Kornfeld, J., & Stokoe, S. (2019). Introducing Chemistry through the Lens of Earth's Systems: What Role Can Systems Thinking Play in Developing Chemically and Environmentally Literate Citizens. *Journal of Chemical Education*, 96(12), 2910–2917. <https://doi.org/10.1021/acs.jchemed.9b00263>.

Lally, Diane, et al. (2019). National Geoscience Faculty Survey 2016 : Prevalence of Systems Thinking and Scientific Modeling Learning Opportunities. *Journal of Geoscience Education*, 2019. ISSN: 1089-9995 (print) 2158-1428 (online) DOI: 10.1080/10899995.2019.1565286.

Laurie, R., Nonoyama-Tarumi, Y., Mckeown, R., & Hopkins, C. (2016). Contributions of Education for Sustainable Development (ESD) to Quality Education: A Synthesis of Research. *Journal of Education for Sustainable Development*, 10(2), 226–242. <https://doi.org/10.1177/0973408216661442>.

Lavi, R., & Dori, Y. J. (2019). Systems thinking of pre- and in-service science and engineering teachers. *International Journal of Science Education*, 41(2), 248–279. <https://doi.org/10.1080/09500693.2018.1548788>.

Lawrance, G. A. (2009). Introduction to Coordination Chemistry. In *Introduction to Coordination Chemistry*. <https://doi.org/10.1002/9780470687123>.

Leach, J., & Scott, P. (2002). Designing and evaluating science teaching sequences: An approach drawing upon the concept of learning demand and a social constructivist perspective on learning. *Studies in Science Education*, 38(1), 115–142. <https://doi.org/10.1080/03057260208560189>.

Lemin, L., Jingqiang, R., and Guangxian, X. (1983) INDO studies on the electronic structure of lanthanide compounds. *International Journal of Quantum Chemistry*, XXIII, 1305–1316.

Lemaoui, T., Abu Hatab, F., Darwish, A. S., Attoui, A., Hammoudi, N. E. H., Almustafa, G., ... & Alnashef, I. M. (2021). Molecular-based guide to predict the pH of eutectic solvents: promoting an efficient design approach for new green solvents. *ACS Sustainable Chemistry & Engineering*, 9(17), 5783-5808.

Leyva-Porras, C., Cruz-Alcantar, P., Espinosa-Solís, V., Martínez-Guerra, E., Piñón-Balderrama, C. I., Compean Martínez, I., and Saavedra-Leos, M. Z. (2019). Application of differential scanning calorimetry (DSC) and modulated differential scanning calorimetry (MDSC) in food and drug industries. *Polymers*, 12(1), 5.

Lijnse, P., & Klaassen, K. (2004). Didactical structures as an outcome of research on teaching-learning sequences? *International Journal of Science Education*,

26(5), 537–554. <https://doi.org/10.1080/09500690310001614753>.

- Lozano, R., & Watson, M. K. (2013). Educación química para la Sustentabilidad. evaluación del currículo de química en la universidad de cardiff. *Educacion Quimica*, 24(2), 184–192. [https://doi.org/10.1016/S0187-893X\(13\)72461-3](https://doi.org/10.1016/S0187-893X(13)72461-3).
- Mahaffy, P. G., Martin, B. E., Kirchhoff, M., McKenzie, L., Holme, T., Versprille, A., & Towns, M. (2014). Infusing sustainability science literacy through chemistry education: Climate science as a rich context for learning chemistry. *ACS Sustainable Chemistry and Engineering*, 2(11), 2488–2494. <https://doi.org/10.1021/sc500415k>.
- Mahaffy, P. G., Matlin, S. A., Holme, T. A., & MacKellar, J. (2019). Systems thinking for education about the sustainability of the molecular level. *Nature Sustainability*, 2(5), 362–370. <https://doi.org/10.1038/s41893-019-0285-3>.
- Mahaffy, P. G., Matlin, S. A., Whalen, J. M., & Holme, T. A. (2019). Integrating the Sustainability of the molecular level into General Chemistry through Systems Thinking. *Journal of Chemical Education*, 96(12), 2730–2741. <https://doi.org/10.1021/acs.jchemed.9b00390>.
- Manley, J. B., Anastas, P. T., & Cue, B. W. (2008). Frontiers in Green Chemistry: meeting the grand challenges for sustainability in R&D and manufacturing. *Journal of Cleaner Production*, 16(6), 743–750. <https://doi.org/10.1016/j.jclepro.2007.02.025>.
- Marcus, Y. (2019). Deep Eutectic Solvents. In *Deep Eutectic Solvents*. <https://doi.org/10.1007/978-3-030-00608-2>.
- Martín-Ramos, P., Miranda, M. D., Silva, M. R., Eusebio, M. E. S., Lavín, V., & Martín-Gil, J. (2013). A new near-IR luminescent erbium(III) complex with potential application in OLED devices. *Polyhedron*, 65(3), 187–192. <https://doi.org/10.1016/j.poly.2013.08.035>.
- Marusak, R. A., Doan, K., & Cummings, S. D. (2007). Integrated Approach to Coordination Chemistry. In *Integrated Approach to Coordination Chemistry*. <https://doi.org/10.1002/047011844x>.
- Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. In *Approaches to qualitative research in mathematics education* (pp. 365–380). Springer.
- Méheut, M., & Psillos, D. (2004). Teaching-learning sequences: Aims and tools for science education research. *International Journal of Science Education*, 26(5), 515–535. <https://doi.org/10.1080/09500690310001614762>.

- Méheut, M. (2005). Teaching-learning sequences tools for learning and/or research. *Research and the Quality of Science Education*, 195–207. [https://doi.org/10.1007/1-4020-3673-6\\_16](https://doi.org/10.1007/1-4020-3673-6_16).
- Miller, J. D. (2004). Public understanding of, and attitudes towards, scientific research: What we know and what we need to know. *Public Understanding of Science*, 13(3), 273–294. doi:10.1177/0963662504044908.
- Mudzakir, A., Hernani, H., Widhiyanti, T., & Sudrajat, D. P. (2017, August). Contribution from philosophy of chemistry to chemistry education: In a case of ionic liquids as technochemistry. In *AIP Conference Proceedings* (Vol. 1868, No. 1). AIP Publishing.
- Muna, I. A. (2018). Studi Komparasi Metode Eksperimen Inkuiri dengan Eksperimen Verifikasi terhadap Hasil Belajar IPA Materi Perpindahan Kalor. *Cendekia: Journal of Education and Society*, 15(2), 264. <https://doi.org/10.21154/cendekia.v15i2.1006>.
- Murugesan, S., & Linhardt, R. J. (2005). Ionic liquids in carbohydrate chemistry-current trends and future directions. *Current Organic Synthesis*, 2(4), 437-451.
- Nanda, B., Sailaja, M., Mohapatra, P., Pradhan, R. K., & Nanda, B. B. (2021). Green solvents: A suitable alternative for sustainable chemistry. *Materials Today: Proceedings*, 47(xxxx), 1234–1240. <https://doi.org/10.1016/j.matpr.2021.06.458>.
- Nentwig, P. M., Demuth, R., Parchmann, I., Gräsel, C., & Ralle, B. (2007). Chemie im Kontext: Situating learning in relevant contexts while systematically developing basic chemical concepts. *Journal of Chemical Education*, 84(9), 1439–1444. <https://doi.org/10.1021/ed084p1439>.
- Niebert, K., & Gropengießer, H. (2013). The model of educational reconstruction: A framework for the design of theory-based content specific interventions. The example of climate change. *Educational Design Research – Part B: Illustrative Cases*, 511–532.
- Niebert, K., & Gropengießer, H. (2014). Understanding the Greenhouse Effect by Embodiment - Analysing and Using Students' and Scientists' Conceptual Resources. *International Journal of Science Education*, 36(2), 277–303. <https://doi.org/10.1080/09500693.2013.763298>.
- Orgill, M. K., York, S., & Mackellar, J. (2019). Introduction to Systems Thinking for the Chemistry Education Community. *Journal of Chemical Education*, 96(12), 2720–2729. <https://doi.org/10.1021/acs.jchemed.9b00169>.
- Pateli, I. M., Abbott, A. P., Binnemans, K., & Rodriguez, N. R. (2020). Recovery

of yttrium and europium from spent fluorescent lamps using pure levulinic acid and the deep eutectic solvent levulinic acid–choline chloride. *Rsc Advances*, 10(48), 28879-28890.

Pauling, L. (1960). Aug. 5, 1960 BOOK REVIEWS 4121. *The of the Chemical Bond and the Structure of Molecules and Crystals: An Introduction to Modern Structural Chemistry*, 10–13.

Petersen, J. E., Frantz, C. M., Tincknell, E., & Canning, C. (2018). An Animated Visual Representation of Real-Time Resource Flows Through a Community Enhances Systems Thinking. *Systems Research and Behavioral Science*, 35(6), 718-737.

Petrucci, R.H., Herring, F.G., Madura, J.D., Bissonnette, C. (2010). *General Chemistry Principle and Modern Applications Tenth Edition*. Toronto, Canada: Pearson.

Pinasti, Titen., Mudzakir, Ahmad., & Hernani. (2021). *Unsur Tanah Jarang : Buku Ajar untuk Mahasiswa Calon Guru Kimia*”. Bandung : Universitas Pendidikan Indonesia.

Ramanayaka, S., Keerthanan, S., & Vithanage, M. (2019). Urban mining of E-waste: Treasure hunting for precious nanometals. In *Handbook of Electronic Waste Management: International Best Practices and Case Studies*. INC. <https://doi.org/10.1016/B978-0-12-817030-4.00023-1>.

Reinfried, S., Aeschbacher, U., Kienzler, P. M., & Tempelmann, S. (2015). The model of educational reconstruction - A powerful strategy to teach for conceptual development in physical geography: The case of water springs. *International Research in Geographical and Environmental Education*, 24(3), 237–257. <https://doi.org/10.1080/10382046.2015.1034459>.

Reynders, M., Pilcher, L. A., & Potgieter, M. (2023). Teaching and Assessing Systems Thinking in First-Year Chemistry. *Journal of Chemical Education*, 100(3), 1357–1365. <https://doi.org/10.1021/acs.jchemed.2c00891>.

Rohonczy, J. (2017). Inorganic chemistry I. In *Inorganic chemistry I*. <https://doi.org/10.21862/inorgchem1-eng>.

Roon, A. Van, Govers, H. A. J., Parsons, J. R., & Weenen, H. Van. (2001). Sustainable chemistry: An analysis of the concept and its integration in education. *International Journal of Sustainability in Higher Education*, 2(2), 161–180. <https://doi.org/10.1108/14676370110388372>.

Rosenkränzer, F., Hörsch, C., Schuler, S., & Riess, W. (2017). Student teachers' pedagogical content knowledge for teaching systems thinking: Effects of

different interventions. *International Journal of Science Education*, 39(14), 1932-1951.

Rumata, V. M. (2017). Analisis Isi Kualitatif Twitter “#TaxAmnesy” dan “#AmnestiPajak.” *Jurnal Penelitian Komunikasi Dan Pembangunan*, 18(1), 1. <https://doi.org/10.31346/jpkp.v18i1.840>.

Salgado, J., Parajó, J. J., Villanueva, M., Rodríguez, J. R., Cabeza, O., & Varela, L. M. (2019). Liquid range of ionic liquid–Metal salt mixtures for electrochemical applications. *The Journal of Chemical Thermodynamics*, 134, 164-174.

Serhan, M., Sprowls, M., Jackemeyer, D., Long, M., Perez, I. D., Maret, W., Tao, N., & Forzani, E. (2019). Total iron measurement in human serum with a smartphone. *AIChE Annual Meeting, Conference Proceedings, 2019-Novem*. <https://doi.org/10.1039/x0xx00000x>.

Seuring, S., Müller, M., Westhaus, M., & Morana, R. (2016). Conducting a Literature Review — The Example of Sustainability in Supply Chains. In *Research Methodologies in Supply Chain Management* (pp. 91–106). Physica-Verlag. [https://doi.org/10.1007/3-7908-1636-1\\_7](https://doi.org/10.1007/3-7908-1636-1_7).

Shwartz, Y., Ben-Zvi, R., & Hofstein, A. (2006). The use of scientific literacy taxonomy for assessing the development of chemical literacy among high-school students. *Chemistry Education Research and Practice*, 7(4), 203–225. doi:10.1039/b6rp90011a.

Singh, V. K., Kawai, J., and Tripathi, D. K. (Eds.). (2022). *X-Ray Fluorescence in Biological Sciences: Principles, Instrumentation, and Applications*. John Wiley & Sons. India.

Sjöström, J., Rauch, F., & Eilks, I. (2015). "Chemistry Education for Sustainability". In *Relevant Chemistry Education*. Leiden, The Netherlands: Brill. Retrieved Nov 1, 2023, from <https://brill.com/view/book/edcoll/9789463001755/BP000010.xml>.

Smith, Emma L.; Abbott, Andrew P.; Ryder, Karl S. (2014). Deep Eutectic Solvents (DESs) and Their Applications. *Chemical Reviews*, 114(21), 11060–11082. doi:10.1021/cr300162p.

Stadler, A. M., & Harrowfield, J. (2009). Bis-acyl-/aroyl-hydrazones as multidentate ligands. *Inorganica Chimica Acta*, 362(12), 4298-4314.

Stavrou, D., Michailidi, E., & Sgouros, G. (2018). Development and dissemination of a teaching learning sequence on nanoscience and nanotechnology in a context of communities of learners. *Chemistry Education Research and*



Practice, 19(4), 1065-1080.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*, 49(1), 1-34. 10.1007/978-3-030-00608-2(Chapter 4), 111–151. doi:10.1007/978-3-030-00608-2\_4.

Su, W., Gao, L., Wang, L., and Zhi, H. (2021). Calibration of differential scanning calorimeter (DSC) for thermal properties analysis of phase change material. *Journal of Thermal Analysis and Calorimetry*, 143(4), 2995-3002.

Suseno, I. (2017). Komparasi Karakteristik Butir Tes Pilihan Ganda Ditinjau Dari Teori Tes Klasik. 4(1), 1–8.

Tanskanen, P. (2013). Management and recycling of electronic waste. *Acta materialia*, 61(3), 1001-1011.

Thermo, N. 2001. Introduction to Fourier Transform Infrared Spectrometry. Thermo Nicolet Corporation: USA.

Tripto, J., Assaraf, O. B.-Z., & Amit, M. (2013). Mapping What They Know: Concept Maps as an Effective Tool for Assessing Students' Systems Thinking. *American Journal of Operations Research*, 03(01), 245–258. <https://doi.org/10.4236/ajor.2013.31a022>.

Tundo, P., Anastas, P., Black, D. S. C., Breen, J., Collins, T., Memoli, S., Miyamoto, J., Polyakoff, M., & Tumas, W. (2000). Synthetic pathways and processes in green chemistry. Introductory overview. *Pure and Applied Chemistry*, 72(7), 1207–1228. <https://doi.org/10.1351/pac200072071207>.

UNESCO. (2018). Issues and Trends in Education for Sustainable Development. In UNESCO Publishing.

Vachliotis, T., Salta, K., & Tzougraki, C. (2014). Meaningful understanding and systems thinking in organic chemistry: Validating measurement and exploring relationships. *Research in Science Education*, 44, 239-266.

Verhoeff, R. P., Waarlo, A. J., & Boersma, K. T. (2008). Systems modelling and the development of coherent understanding of cell biology. *International Journal of Science Education*, 30(4), 543–568. <https://doi.org/10.1080/09500690701237780>.

Vesterinen, V. M., Tolppanen, S., & Aksela, M. (2016). Toward citizenship science education: what students do to make the world a better place? *International Journal of Science Education*, 38(1), 30–50. <https://doi.org/10.1080/09500693.2015.1125035>.

- Viennot, L., & Rainson, S. (1999). Design and evaluation of a research-based teaching sequence: The superposition of electric field. *International Journal of Science Education*, 21(1), 1–16. <https://doi.org/10.1080/095006999290804>.
- Voncken, J. H. L. (2016). The rare earth elements: an introduction. Cham, Switzerland: Springer International Publishing.
- Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies*, 44(3), 299–321. doi:10.1080/00220272.2012.668938.
- Ware, S. A. (2001). Teaching chemistry from a societal perspective. *Pure and Applied Chemistry*, 73(7), 1209–1214. doi:10.1351/pac200173071209.
- Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6(2), 203–218.
- Wilensky, U., Reisman, K., & Taylor, P. (2018). *Thinking like a Wolf, a Sheep, or a Firefly: Learning Biology through Constructing and Testing Computational Theories-An Embodied Modeling Approach Thinking Like a Wolf, a Sheep, or a Firefly: Learning Biology Through Constructing and Testing An Emb.* 24(2), 171–209.
- Wilmes, Sara; Howarth, J. (2009). Using Science in The Classroom in the Classroom. *Science Teacher*, 76(7), 24–29.
- Wilson, A. M., Bailey, P. J., Tasker, P. A., Turkington, J. R., Grant, R. A., & Love, J. B. (2014). Solvent extraction: The coordination chemistry behind extractive metallurgy. *Chemical Society Reviews*, 43(1), 123–134. <https://doi.org/10.1039/c3cs60275c>.
- Yusmaita, E., & Nasra, E. (2017). Perancangan Assesmen Literasi Kimia Dengan Menggunakan Model of Educational Rekonstruction (Mer) Pada Tema: “Air Sebagai Pelarut Universal.” *Jurnal Eksakta Pendidikan (Jep)*, 1(2), 49. <https://doi.org/10.24036/jep.v1i2.66>.
- Zhang, Q., Zhang, S., Deng, Y. (2011). Recent advances in ionic liquid catalysis. *Green Chem* (13). 2619-2637. DOI: 10.1039/c1gc15334j.
- Zoller, U. (2004). Chemistry and environmental education. *Chemistry Education Research and Practice*, 5(2), 95–97. doi:10.1039/b4rp90014f.

Zuza, K., De Cock, M., Van Kampen, P., Kelly, T., & Guisasola, J. (2020). Guiding students towards an understanding of the electromotive force concept in electromagnetic phenomena through a teaching-learning sequence. *Physical Review Physics Education Research*, 16(2), 20110. <https://doi.org/10.1103/PhysRevPhysEducRes.16.020110>.