PENGEMBANGAN *GAME* EDUKASI BERBASIS INTERTEKSTUAL UNTUK MENGKONSTRUKSI MODEL MENTAL PESERTA DIDIK PADA KONSEP PENGARUH SIFAT PEREAKSI TERHADAP LAJU REAKSI

TESIS

diajukan untuk memenuhi sebagian syarat memperoleh gelar Magister Pendidikan
Program Studi Pendidikan Kimia

oleh
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PROGRAM STUDI PENDIDIKAN KIMIA
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA
2024

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PENGEMBANGAN *GAME* EDUKASI BERBASIS INTERTEKSTUAL
UNTUK MENGKONSTRUKSI MODEL MENTAL PESERTA DIDIK PADA
KONSEP PENGARUH SIFAT PEREAKSI TERHADAP LAJU REAKSI

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PERNYATAAN KEASLIAN TESIS DAN BEBAS PLAGIARISME

Dengan ini saya menyatakan bahwa tesis dengan judul "Pengembangan *Game* Edukasi Berbasis Intertekstual untuk Mengkonstruksi Model Mental Peserta Didik Pada Konsep Pengaruh Sifat Pereaksi terhadap Laju Reaksi" ini beserta seluruh isinya adalah benar-benar karya saya sendiri dengan bimbingan dari dosen pembimbing. Saya tidak melakukan penjiplakan atau pengutipan dengan cara-cara yang tidak sesuai dengan etika ilmu yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, saya siap menanggung risiko ataupun sanksi apabila dikemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain dari pihak lain terhadap keaslian karya saya ini.

Bandung, 30 Juli 2024
Yang Membuat Pernyataan

Chintya Desty Octavia,

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ABSTRAK

Penelitian ini bertujuan untuk menghasilkan produk game edukasi berbasis intertekstual yang dapat mengkonstruksi model mental peserta didik pada konsep pengaruh sifat pereaksi terhadap laju reaksi. Metode penelitian yang digunakan yaitu R&D dengan model Borg & Gall. Pada tahap uji coba, kelas eksperimen diberikan perlakuan menggunakan game edukasi berbasis intertekstual, sedangkan kelas kontrol diberikan perlakuan dengan pembelajaran konvensional berbantuan buku teks berbasis intertekstual. Untuk mengukur model mental peserta didik, peneliti menggunakan wawancara TDM-IAE dengan tujuh peserta didik dari masing-masing kelompok, baik sebelum maupun setelah perlakuan. Selain itu, peneliti juga mengumpulkan tanggapan dari 40 peserta didik kelas eksperimen dan 2 guru kimia mengenai produk *game* edukasi berbasis intertekstual. Penelitian ini menghasilkan produk *game* edukasi berbasis intertekstual pada konsep pengaruh sifat pereaksi terhadap laju reaksi dengan mempertimbangkan tiga aspek, yaitu aspek konten, pedagogi, dan multimedia yang telah valid. Hasil penelitian menunjukkan bahwa peserta didik yang belajar menggunakan *game* edukasi lebih mampu membangun model mental yang utuh mengenai konsep pengaruh sifat pereaksi terhadap laju reaksi daripada peserta didik kelas kontrol. Analisis mendalam terhadap hasil wawancara TDM-IAE mengungkapkan bahwa peserta didik kelas eksperimen lebih mampu mengkonstruksi konsep dengan baik, seperti konsep pengaruh struktur molekul, energi ionisasi, dan luas permukaan bidang sentuh terhadap laju reaksi daripada peserta didik kelas kontrol. Berdasarkan hasil tanggapan, kedua guru menyatakan setuju terhadap kejelasan aspek konten, video, dan gambar, kemudahan navigasi, dan peran *game* edukasi sebagai media alternatif yang bersifat interaktif. Selain itu, mayoritas peserta didik memberikan tanggapan yang positif terkait *game* edukasi.

Kata kunci: *game* edukasi, intertekstual, model mental, laju reaksi

ABSTRACT

This study aims to produce an intertextual-based educational game product that can construct students' mental models on the concept of the influence of reactant properties on reaction rates. The research method used is R&D with the Borg & Gall model. In the trial stage, the experimental class was given treatment using intertextual-based educational games, while the control class was given treatment with conventional learning assisted by intertextual-based textbooks. To measure students' mental models, the researcher used TDM-IAE interviews with seven students from each group, both before and after treatment. In addition, the researcher also collected responses from 40 experimental class students and 2 chemistry teachers regarding intertextual-based educational game products. This study produced an intertextual-based educational game product on the concept of the influence of reactant properties on reaction rates by considering three aspects, namely content, pedagogy, and multimedia aspects that have been validated. The results showed that students who learned using educational games were better able to build a complete mental model regarding the concept of the influence of reactant properties on reaction rates than students in the control class. In-depth analysis of the TDM-IAE interview results revealed that experimental class students were better able to construct concepts well, such as the concept of the influence of molecular structure, ionization energy, and surface area of the contact area on reaction rates than control class students. Based on the response results, both teachers agreed with the clarity of content, video, and image aspects, ease of navigation, and the role of educational games as an interactive alternative media. In addition, the majority of students gave positive responses regarding educational games.

Keywords: educational game, intertextual, mental models, reaction rate

DAFTAR ISI

DAFTAR PUSTAKA

Agarwal, M., & Saha, S. (2011). Learning Chemistry Through Puzzle Based Game: Atoms to Molecule. *IIEE International Conference on Emerging ELearning Technologies and Application*, 189–193.

Antunes, M., Pacheco, M. A. R., & Giovanela, M. (2012). Design and implementation of an educational game for teaching chemistry in higher education. *Journal of Chemical Education*, *89*(4), 517–521. https://doi.org/10.1021/ed2003077

Arifah, R., & Marzuki, I. (2021). Constructivism Theory of Learning Solutions During The Covid-19 Pandemic in Indonesia. *International Journal of Education, Information Technology and Others (IJEIT)*, *4*(1), 91–96.

Arifudin, D., Suliswaningsih, Pramesti, D., & Heryanti, L. (2022). Implementasi Game Design Document pada Perancangan Game-based Learning Implementation of Game Design Documents in Game Design Based Learning. *Cogito Smart Journal*, *8*(2), 385–397.

Bakhtin, M. M. (1981). *The Dialogic Imagination: Four Essays* (Michael Holquist). University of Texas Press.

Bang, H. J., Li, L., & Flynn, K. (2023). Efficacy of an Adaptive Game-Based Math Learning App to Support Personalized Learning and Improve Early Elementary School Students' Learning. *Early Childhood Education Journal*, *51*(4), 717–732. https://doi.org/10.1007/s10643-022-01332-3

Barke, H. D., Hazari, A., & Yitbarek, S. (2009). Misconceptions in chemistry: Addressing perceptions in chemical education. In *Misconceptions in Chemistry: Addressing Perceptions in Chemical Education*. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-70989-3

Barke, H.-D. (2017). CHEMISTRY AT ELEMENTARY SCHOOLS: PARTICLES OR ALSO ATOMS-THAT'S THE QUESTION. *African Journal of Chemical Education-AJCE*, *7*(2).

Bazerman, C. (2003). Intertextuality: How Texts Rely on Other Texts 1. In *What Writing Does and How It Does It* (pp. 83–96). Lawrence Erlbaum Associates, Inc.,.

Bintang, A., Danial, M., & Ramlawati, R. (2019). PENGEMBANGAN BAHAN AJAR ELEKTRONIK SCIENCE FLASHBOOK MATA PELAJARAN IPA KELAS VIII SMP PADA MATERI POKOK PARTIKEL. *Chemistry Education Review (CER)*, *2*(2), 1. https://doi.org/10.26858/cer.v2i2.8671

Boyan, A., & Sherry, J. L. (2011). The Challenge in Creating Games for Education: Aligning Mental Models With Game Models. *Child Development Perspectives*, *5*(2), 82–87.

Brady, J. E., Jespersen, N. D., & Hyslop, A. (2012). *Chemistry: The Molecular Nature of Matter* (Vol. 6).

Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C., & Woodward, P. M. (2012). *Chemistry: The Central Science* (Vol. 12).

Bucciarelli, M. (2007). How the construction of mental models improves learning. *Mind and Society*, *6*(1), 67–89. https://doi.org/10.1007/s11299-006-0026-y

Byusa, E., Kampire, E., & Mwesigye, A. R. (2022). Game-based learning approach on students' motivation and understanding of chemistry concepts: A systematic review of literature. In *Heliyon* (Vol. 8, Issue 5). Elsevier Ltd. https://doi.org/10.1016/j.heliyon.2022.e09541

Çalik, M., Kolomuç, A., & Karagölge, Z. (2010). The Effect of Conceptual Change Pedagogy on Students' Conceptions of Rate of Reaction. *Journal of Science Education and Technology*, *19*(5), 422–433. https://doi.org/10.1007/s10956-010-9208-9

Çalýk, M., Ayas, A., & Ebenezer, J. V. (2005). A review of solution chemistry studies: Insights into students' conceptions. In *Journal of Science Education and Technology* (Vol. 14, Issue 1, pp. 29–50). https://doi.org/10.1007/s10956-005-2732-3

Chairam, S., Somsook, E., & Coll, R. K. (2009). Enhancing Thai students' learning of chemical kinetics. *Research in Science and Technological Education*, *27*(1), 95–115. https://doi.org/10.1080/02635140802658933

Chandrasegaran, A. L., Treagust, D. F., & Mocerino, M. (2007). The development of a two-tier multiple-choice diagnostic instrument for evaluating secondary school students' ability to describe and explain chemical reactions using multiple levels of representation. In *Educ. Res. Pract* (Vol. 8, Issue 3).

Chang, C. C., & Yang, S. T. (2023). Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners' emotion, cognitive load and learning performance. *International Journal of Educational Technology in Higher Education*, *20*(1). https://doi.org/10.1186/s41239-023-00385-7

Chang, Raymond. (2010). *Chemistry*. McGraw-Hill.

Chen, C. H., Huang, K., & Liu, J. H. (2020a). Inquiry-Enhanced Digital Game-Based Learning: Effects on Secondary Students' Conceptual Understanding in Science, Game Performance, and Behavioral Patterns. *Asia-Pacific Education Researcher*, *29*(4), 319–330. https://doi.org/10.1007/s40299-019-00486-w

Chen, C. H., Huang, K., & Liu, J. H. (2020b). Inquiry-Enhanced Digital Game-Based Learning: Effects on Secondary Students' Conceptual Understanding in Science, Game Performance, and Behavioral Patterns. *Asia-Pacific Education Researcher*, *29*(4), 319–330. https://doi.org/10.1007/s40299-019-00486-w

Chen, S., Jamiatul Husnaini, S., & Chen, J. J. (2020). Effects of games on students' emotions of learning science and achievement in chemistry. *International Journal of Science Education*, *42*(13), 2224–2245. https://doi.org/10.1080/09500693.2020.1817607

Cheng, M. T., Huang, W. Y., & Hsu, M. E. (2019). Does emotion matter? An investigation into the relationship between emotions and science learning outcomes in a game-based learning environment. *British Journal of Educational Technology*, *51*(6), 2233–2251. https://doi.org/10.1111/bjet.12896

Chittleborough, G. D. (2004). *The Role of Teaching Models and Chemical Representations in Developing Students' Mental Models of Chemical Phenomena* [Thesis]. Curtin University of Technology.

Chittleborough, G., & Treagust, D. F. (2007). The modelling ability of non-major chemistry students and their understanding of the sub-microscopic level. *The Royal Society of Chemistry*, *8*(3), 274–292.

Coll, R. K., & Treagust, D. F. (2003). Investigation of secondary school, undergraduate, and graduate learners' mental models of ionic bonding.

Journal of Research in Science Teaching, *40*(5), 464–486.
https://doi.org/10.1002/tea.10085

Culler, J. (2001). *The Pursuit of Signs: Semiotics, Literature, Deconstruction*.
Routledge Classics.

Daubenfeld, T., & Zenker, D. (2015). A game-based approach to an entire physical
chemistry course. *Journal of Chemical Education*, *92*(2), 269–277.
https://doi.org/10.1021/ed5001697

Devetak, I., Vogrinc, J., & Glažar, S. A. (2009). Assessing 16-year-old students'
understanding of Aqueous solution at submicroscopic level. *Research in
Science Education*, *39*(2), 157–179. https://doi.org/10.1007/s11165-007-
9077-2

Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for
improving science teaching and learning. *International Journal of Science
Education*, *25*(6), 671–688. https://doi.org/10.1080/09500690305016

Eastwood, M. L. (2013). Fastest fingers: A molecule-building game for teaching
organic chemistry. *Journal of Chemical Education*, *90*(8), 1038–1041.
https://doi.org/10.1021/ed3004462

Fahmi, F., & Irhasyuarna, Y. (2017). Misconceptions of Reaction Rates on High
School Level in Banjarmasin. *IOSR Journal of Research & Method in
Education (IOSRJRME)*, *07*(01), 54–61. https://doi.org/10.9790/7388-
0701045461

Fazio, C., Battaglia, O. R., & Di Paola, B. (2013). Investigating the quality of
mental models deployed by undergraduate engineering students in creating
explanations: The case of thermally activated phenomena. *Physical Review
Special Topics - Physics Education Research*, *9*(2).
https://doi.org/10.1103/PhysRevSTPER.9.020101

Femintasari, V., & Munzil, &. (2015). THE EFFECTIVENESS OF TWO-TIER
MULTIPLE CHOICE TEST AND MULTIPLE CHOICE TEST
FOLLOWED WITH INTERVIEW IN IDENTIFYING MISCONCEPTION
OF STUDENTS WITH DIFFERENT SCIENTIFIC REASONING SKILLS
IN REACTION RATE. *Jurnal Ilmu Pendidikan*, *21*(2), 192–197.

Filsecker, M., & Kerres, M. (2014). Engagement as a Volitional Construct: A Framework for Evidence-Based Research on Educational Games. *Simulation and Gaming*, *45*, 450–470. https://doi.org/10.1177/1046878114553569

Fitria, D., Jamaris, & Sufyarma. (2021). Implementation of Constructivism Learning Theory in Science. *International Journal Of Humanities Education And Social Sciences (IJHESS)*, *1*(3), 228–235. https://ijhess.com/index.php/ijhess/

Gabel, D. (1999). Improving Teaching and Learning through Chemistry Education Research: A Look to the Future*. In *Research: Science and Education 548 Journal of Chemical Education* • (Vol. 76, Issue 4).

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational Research: An Introduction* (Burvikovs Arnis E., M. Kriener, & C. Tridente, Eds.; 7th ed.). Pearson Education, Inc.

Garris, R., Ahlers, R., & Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation and Gaming*, *33*(4), 441–467. https://doi.org/10.1177/1046878102238607

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

Greca, I. M., & Moreira, M. A. (2002). Mental, Physical, and Mathematical Models in the Teaching and Learning of Physics. *Science Education*, *86*(1), 106–121. https://doi.org/10.1002/sce.10013

Gunarti, D., Rohman, I., & Khoerunnisa, F. (2017). *AN ANALYSIS OF STUDENTS' MISCONCEPTION AND LEARNING METHODS USED IN CONFIRMING SURFACE AREA CONCEPTS IN RATE REACTION TOPIC AS BASIC TO DEVELOP SURFACE AREA GAME*.

Hakimah, N., Muchson, M., Herunata, H., Permatasari, M. B., & Santoso, A. (2021). Identification student misconceptions on reaction rate using a Google forms three-tier tests. *AIP Conference Proceedings*, *2330*. https://doi.org/10.1063/5.0043114

Hamari, J., Shernoff, D. J., Rowe, E., Coller, B., Asbell-Clarke, J., & Edwards, T. (2016). Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning. *Computers in Human Behavior*, *54*, 170–179. https://doi.org/10.1016/j.chb.2015.07.045

Hamstra, B. J. (2020). Using Toys to Introduce Symmetry Analysis in a Senior-Level Inorganic Chemistry Course. In *ACS Symposium Series* (Vol. 1370, pp. 77–85). American Chemical Society. https://doi.org/10.1021/bk-2020-1370.ch007

Harianto, A., & Yenti, E. (2021). DESAIN DAN UJI COBA GAME EDUKASI KIMIA BERBASIS ROLE PLAYING GAME (RPG) PADA MATERI LAJU REAKSI. *JEDCHEM (Journal Education and Chemistry*, *3*(1), 4–10.

Hayes, A. (2017a). Using mental models to design for learning: Lessons from game development. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10295 LNCS*, 433–442. https://doi.org/10.1007/978-3-319-58509-3_34

Hayes, A. (2017b). Using mental models to design for learning: Lessons from game development. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, *10295 LNCS*, 433–442. https://doi.org/10.1007/978-3-319-58509-3_34

Holtrop, J. S., Scherer, L. D., Matlock, D. D., Glasgow, R. E., & Green, L. A. (2021). The Importance of Mental Models in Implementation Science. *Frontiers in Public Health*, *9*. https://doi.org/10.3389/fpubh.2021.680316

Hsu, C. Y., & Tsai, C. C. (2013). Examining the effects of combining self-explanation principles with an educational game on learning science concepts. *Interactive Learning Environments*, *21*(2), 104–115. https://doi.org/10.1080/10494820.2012.705850

Hsu, C.-Y., Tsai, C.-C., & Liang, J.-C. (2011). Facilitating Preschoolers' Scientific Knowledge Construction via Computer Games Regarding Light and Shadow: The Effect of the Prediction-Observation-Explanation (POE) Strategy. In *Source: Journal of Science Education and Technology* (Vol. 20, Issue 5). https://www.jstor.org/stable/41499417

Hu, Y., Gallagher, T., Wouters, P., van der Schaaf, M., & Kester, L. (2022). Game-based learning has good chemistry with chemistry education: A three-level meta-analysis. *Journal of Research in Science Teaching*, *59*(9), 1499–1543. https://doi.org/10.1002/tea.21765

Huang, K., Ge, X., & Eseryel, D. (2017). Metaconceptually-enhanced simulation-based inquiry: effects on eighth grade students' conceptual change and science epistemic beliefs. *Educational Technology Research and Development*, *65*(1), 75–100. https://doi.org/10.1007/s11423-016-9462-5

Hwang, D., & Kang, Y. (2023). How Does constructive feedback in an educational game sound to children? *International Journal of Child-Computer Interaction*, *36*. https://doi.org/10.1016/j.ijcci.2023.100581

Ibrahim, B., & Rebello, N. S. (2013). Role of mental representations in problem solving: Students' approaches to nondirected tasks. *Physical Review Special Topics - Physics Education Research*, *9*(2). https://doi.org/10.1103/PhysRevSTPER.9.020106

Indriawati, S., Sunardi, & Kurniati, D. (2017). PENGEMBANGAN INDIKATOR 4 C's YANG SELARAS DENGAN KURIKULUM 2013 PADA MATA PELAJARAN MATEMATIKA SMP/MTs KELAS IX SEMESTER 1. *Kadikma*, *8*(2), 178–188.

Iqbal, M., Lasmana Tarigan, I., Studi Kimia, P., & Jambi, U. (2019). PENGARUH MODEL PEMBELAJARAN SIKLUS BELAJAR 5E MENGGUNAKAN MEDIA ANIMASI TERHADAP AKTIVITAS BELAJAR DAN HASIL BELAJAR SISWA SMA KELAS XI PADA MATERI HIDROLISIS GARAM. In *Jurnal Pembelajaran Kimia OJS* (Vol. 4, Issue 1).

Jansoon, N., Coll, R. K., & Somsook, E. (2009). *Understanding Mental Models of Dilution International Journal of Environmental & Science Education Understanding Mental Models of Dilution in Thai Students*. http://www.ijese.com/

Jasdilla, L., Fitria, Y., & Sopandi, W. (2019). Predict Observe Explain (POE) strategy toward mental model of primary students. *Journal of Physics: Conference Series*, *1157*(2). https://doi.org/10.1088/1742-6596/1157/2/022043

Jere, S., & Mpeta, M. (2024). Enhancing Learners' Conceptual Understanding of Reaction Kinetics Using Computer Simulations – A Case Study Approach. *Research in Science Education*. https://doi.org/10.1007/s11165-024-10182-5

Johnstone, A. H. (1991). Why is science difficult to learn? Things are seldom what they seem. In *Journal of Computer Assisted Learning* (Vol. 7).

Johnstone, A. H. (1993). *Symposium on fievolution and Evolution in Chemical €ducation The Development of Chemistry Teaching A Changing Response to Changing Demand*.

Johnstone, A. H. (1997). Chemical Education Today Chemistry Teaching-Science or Alchemy? 199Lecture6 Brasted. In *Journal of Chemical Education* • (Vol. 74, Issue 3). https://pubs.acs.org/sharingguidelines

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2020). Misconceptions in rate of reaction and their impact on misconceptions in chemical equilibrium. *European Journal of Educational Research*, *9*(4), 1405–1423. https://doi.org/10.12973/eu-jer.9.4.1405

Ke, F. (2016). Designing and integrating purposeful learning in game play: a systematic review. *Educational Technology Research and Development*, *64*(2), 219–244. https://doi.org/10.1007/s11423-015-9418-1

Kemendikbud. (n.d.). *Permendikbud Nomor 37 Tahun 2018*.

Kemenristekdikti. (2022). *Keputusan Kepala BSKAP No. 33 th. 2022 tentang Perubahan Capaian Pembelajaran*.

Kholidinata, F., Wiji, & Yuliani, G. (2023). Profil Model Mental Siswa Pada Materi Hidrolisis Garam Berdasarkan Strategi Evaluasi Model Predict-Observe-Explain (POE). *Jurnal Riset Dan Praktik Pendidikan Kimia*, *11*(2), 142–154.

Kirik, Ö. T., & Boz, Y. (2012). Cooperative learning instruction for conceptual change in the concepts of chemical kinetics. *Chemistry Education Research and Practice*, *13*(3), 221–236. https://doi.org/10.1039/c1rp90072b

Kolomuç, A., & Tekin, S. (2011). Chemistry Teachers' Misconceptions Concerning Concept of Chemical Reaction Rate. In *Eurasian J. Phys. Chem. Educ* (Vol. 3, Issue 2). http://www.eurasianjournals.com/index.php/ejpce

Kurt, S., & Ayas, A. (2012). Improving students' understanding and explaining real life problems on concepts of reaction rate by using a four step constructivist approach. In *Energy Education Science and Technology Part B: Social and Educational Studies* (Vol. 4, Issue 2).

Lamichhane, R., Reck, C., & Maltese, A. V. (2018). Undergraduate chemistry students' misconceptions about reaction coordinate diagrams. *Chemistry Education Research and Practice*, *19*(3), 834–845. https://doi.org/10.1039/c8rp00045j

Lemke, J. L. (1990). *Talking Science: Language, Learning, and Values (Language and Educational Processes)*. Ablex Publishing Corporation.

Lestari, L. A., Subandi, & Habiddin. (2021). Identifikasi Miskonsepsi Siswa pada Materi Laju Reaksi dan Perbaikannya Menggunakan Model Pembelajaran Learning Cycle 5E dengan Strategi Konflik Kognitif. *Jurnal Pendidikan: Teori, Penelitian, Dan Pengembangan*, *6*(6), 888–894. http://journal.um.ac.id/index.php/jptpp/

Linda, R., Erviyenni, ;, Noer, A. M., Nur, ;, Oktavianti, A., & Sellyna, D. N. (2016). Development of Lectora Inspire as Interactive Multimedia Chemistry Learning in Senior High School. In *Jurnal Pendidikan Kimia* (Vol. 8, Issue 3). http://jurnal.unimed.ac.id/2012/index.php/jpk

Liu, C. J., Hou, I. L., Chiu, H. L., & Treagust, D. F. (2014). An Exploration of Secondary Students' Mental States When Learning About Acids and Bases. *Research in Science Education*, *44*(1), 133–154. https://doi.org/10.1007/s11165-013-9373-y

Malone, T. W. (1981). Toward a Theory of Intrinsically Instruction* Motivating. In *COGNITIVE SCIENCE* (Vol. 4).

Manggopa, H. K., Komansilan, T., Kumajas, S., & Batmetan, J. R. (2022). Storyboard Development for Geospatial e-Tourism Based Augmented Reality. *International Journal of Information Technology and Education (IJITE)*, *1*(3), 56. http://ijite.jredu.idhttp://ijite.jredu.id

Marzabal, A., Delgado, V., Moreira, P., Barrientos, L., & Moreno, J. (2018). Pedagogical Content Knowledge of Chemical Kinetics: Experiment Selection Criteria to Address Students' Intuitive Conceptions. In *Journal of Chemical*

Education (Vol. 95, Issue 8, pp. 1245–1249). American Chemical Society. https://doi.org/10.1021/acs.jchemed.8b00296

Mavridis, A., & Tsiatsos, T. (2017). Game-based assessment: investigating the impact on test anxiety and exam performance. *Journal of Computer Assisted Learning*, *33*(2), 137–150. https://doi.org/10.1111/jcal.12170

Mayer, R. E. (2017). Using Multimedia for e-Learning. *Journal of Computer Assisted Learning*, *33*(5), 403–423. https://doi.org/10.1111/jcal.12197

McClary, L., & Talanquer, V. (2011). College chemistry students' mental models of acids and acid strength. *Journal of Research in Science Teaching*, *48*(4), 396–413. https://doi.org/10.1002/tea.20407

Mewengkang, A., Rampe, M. J., & Palilingan, S. C. (2020). Penerapan Media Pembelajaran Berbasis Video Animasi pada Materi Laju Reaksi dan Faktor-Faktor yang Mempengaruhi Laju Reaksi. *Oxygenius*, *2*(1), 29–33.

Moje, E. B., Collazo, T., Carrillo, R., & Marx, R. W. (2001). "Maestro, What is 'Quality'?": Language, Literacy, and Discourse in Project-Based Science. *Journal of Research in Science Teaching*, *38*(4), 469–498.

Nazar, M., Sulastri, Winarni, S., & Fitriana, R. (2010). Identifikasi Miskonsepsi Siswa SMA Pada Konsep Faktor-faktor yang Mempengaruhi Laju Reaksi (Identification of Senior High School Students' Misconceptions In Concept of Factors That Affect Chemical Reaction Rate). *Journal Biologi Edukasi*.

Nenohai, J. A., Rokhim, D. A., Agustina, N. I., & Munzil, M. (2022). Development of Gamification-Based Wordwall Game Platform on Reaction Rate Materials. *Orbital*, *14*(2), 116–122. https://doi.org/10.17807/orbital.v14i2.16206

Ninaus, M., Greipl, S., Kiili, K., Lindstedt, A., Huber, S., Klein, E., Karnath, H. O., & Moeller, K. (2019). Increased emotional engagement in game-based learning – A machine learning approach on facial emotion detection data. *Computers and Education*, *142*. https://doi.org/10.1016/j.compedu.2019.103641

Nurajizah, S. (2016). Implementasi Multimedia Development Life Cycle Pada Aplikasi Pengenalan Lagu Anak-Anak Berbasis Multimedia. *Jurnal PROSISKO*, *3*(2).

Olankanmi, E. E. (2015). The Effects of a Web-based Computer Simulation on Students' Conceptual Understanding of Rate of Reaction and Attitude Towards Chemistry. *Journal of Baltic Science Education*, *14*(5), 627–640.

Özhan, Ş. Ç., & Kocadere, S. A. (2020). The Effects of Flow, Emotional Engagement, and Motivation on Success in a Gamified Online Learning Environment. *Journal of Educational Computing Research*, *57*(8), 2006–2031. https://doi.org/10.1177/0735633118823159

Pamungkas, M. S. H., Mulyani, S., & Saputro, S. (2017). PENERAPAN MODEL PEMBELAJARAN POE DENGAN METODE PRAKTIKUM UNTUK MENINGKATKAN RASA INGIN TAHU DAN PRESTASI BELAJAR KIMIA SISWA. *PAEDAGOGIA*, *20*(1), 46. https://doi.org/10.20961/paedagogia.v20i1.16596

Pappas, C. C., Varelas, M., Barry, A., & Rife, A. (2003). *Dialogic Inquiry around Information Texts: The Role of Intertextuality in Constructing Scientific Understandings in Urban Primary Classrooms*.

Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015a). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers and Education*, *86*, 30–42. https://doi.org/10.1016/j.compedu.2015.02.016

Park, B., Knörzer, L., Plass, J. L., & Brünken, R. (2015b). Emotional design and positive emotions in multimedia learning: An eyetracking study on the use of anthropomorphisms. *Computers and Education*, *86*, 30–42. https://doi.org/10.1016/j.compedu.2015.02.016

Petrucci, R. H. . (2011). *General chemistry : principles and modern applications*. Pearson Canada.

Plass, J. L., Heidig, S., Hayward, E. O., Homer, B. D., & Um, E. (2014). Emotional design in multimedia learning: Effects of shape and color on affect and learning. *Learning and Instruction*, *29*, 128–140. https://doi.org/10.1016/j.learninstruc.2013.02.006

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based Learning. *Educational Psychologist*, *50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Plass, J. L., Homer, B. D., MacNamara, A., Ober, T., Rose, M. C., Pawar, S., Hovey, C. M., & Olsen, A. (2020). Emotional design for digital games for learning: The effect of expression, color, shape, and dimensionality on the affective quality of game characters. *Learning and Instruction*, *70*. https://doi.org/10.1016/j.learninstruc.2019.01.005

Plass, J. L., & Kaplan, U. (2015). Emotional Design in Digital Media for Learning. In *Emotions, Technology, Design, and Learning* (pp. 131–161). Elsevier. https://doi.org/10.1016/B978-0-12-801856-9.00007-4

Prensky, M. (2001). Digital Natives, Digital Immigrants Part 2: Do They Really Think Differently? *On the Horizon*, *9*(6), 1–6. https://doi.org/10.1108/10748120110424843

Puteri, N. A., & Novita, D. (2015). DEVELOPMENT OF INTERACTIVE MULTIMEDIA ON REACTION RATE TOPIC FOR ELEVENTH-GRADE SENIOR HIGH SCHOOL STUDENT. *UNESA Journal of Chemical Education*, *4*(3), 516–523.

Rahayu, I., . W., Widhiyanti, T., & Mulyani, S. (2024). Analysis of Misconceptions on the Factors that Affect the Reaction Rate. *KnE Social Sciences*. https://doi.org/10.18502/kss.v9i13.15914

Rahayu, I., Wiji, W., Yuliani, G., Widhiyanti, T., & Mulyani, S. (2023). Mental model of the influence of reactant properties on reaction rate. *Jurnal Pendidikan Kimia (JPKIM)*, *15*(3), 208–213. https://doi.org/10.24114/jpkim.v15i3.50411

Rahmayanti, P., Neviyarni, & Nirwana, H. (2021). Application Of Constructivism Theory Of Cooperative Learning Model In Learning. *Literasi Nusantara*, *2*(1). https://doi.org/10.21107/literasinusantara.v2n1.298

Ramos, S., Pimentel, E. P., Marietto, M. das G. B., & Botelho, W. T. (2016). Hands-on and Virtual Laboratories to Undergraduate Chemistry Education: Toward a Pedagogical Integration. *Frontier in Education Conference*, 1–8.

Rastegarpour, H., & Marashi, P. (2012). The effect of card games and computer games on learning of chemistry concepts. *Procedia - Social and Behavioral Sciences*, *31*, 597–601. https://doi.org/10.1016/j.sbspro.2011.12.111

Reigeluth, C. M., Beatty, B. J., & Myers, R. D. (2016). *Instructional-Design Theories and Models: The Learner-Center Paradigm of Education: Vol. IV*.

Ryu, M., Nardo, J. E., & Wu, M. Y. M. (2018). An examination of preservice elementary teachers' representations about chemistry in an intertextuality- and modeling-based course. *Chemistry Education Research and Practice*, *19*(3), 681–693. https://doi.org/10.1039/c7rp00150a

Sabourin, J. L., & Lester, J. C. (2014). Affect and engagement in game-based learning environments. *IEEE Transactions on Affective Computing*, *5*(1), 45–56. https://doi.org/10.1109/T-AFFC.2013.27

Santos, V. C., & Arroio, A. (2016). The representational levels: Influences and contributions to research in chemical education. *Journal of Turkish Science Education*, *13*(1), 3–18. https://doi.org/10.12973/tused.10153a

Sari, W. K., Supriatna, A., & Hendayana, S. (2019). Analysis of students difficulties based on respondents ability test on the topic of factors affecting reaction rate. *Journal of Physics: Conference Series*, *1157*(4). https://doi.org/10.1088/1742-6596/1157/4/042032

Short, K. G. (1992). Researching Intertextuality Within Collaborative Classroom Learning Environments. In *LINGUISTICS AND EDUCATION* (Vol. 4).

Shute, V. J., & Ke, F. (2012). Games, learning, and assessment. In *Assessment in Game-Based Learning: Foundations, Innovations, and Perspectives* (pp. 43–58). Springer New York. https://doi.org/10.1007/978-1-4614-3546-4_4

Silberberg, M. S. . (2013). *Principles of general chemistry*. McGraw-Hill.

Sirhan, G. (2007). Learning Difficulties in Chemistry: An Overview. *Turkish Science Education*, *4*(2). http://www.tused.org

Siswaningsih, W., Anisa, N., Komalasari, E., & Indah, D. (2014). PENGEMBANGAN TES DIAGNOSTIK TWO-TIER UNTUK MENGIDENTIFIKASI MISKONSEPSI PADA MATERI KIMIA SISWA SMA. *Jurnal Pengajaran MIPA*, *19*(1), 117–127.

Solin, A. (2004). Intertextuality as mediation: On the analysis of intertextual relations in public discourse*. *Text - Interdisciplinary Journal for the Study of Discourse*, *24*(2), 267–296.

Srisawasdi, N. (2018). *Cox and Schatzberg; International Perspectives on Chemistry Education Research and Practice ACS Symposium Series* (Vol. 10). American Chemical Society. https://pubs.acs.org/sharingguidelines

Sun, L., Kangas, M., & Ruokamo, H. (2023). Game-based features in intelligent game-based learning environments: a systematic literature review. In *Interactive Learning Environments*. Routledge. https://doi.org/10.1080/10494820.2023.2179638

Supasorn, S. (2015). Grade 12 students' conceptual understanding and mental models of galvanic cells before and after learning by using small-scale experiments in conjunction with a model kit. *Chemistry Education Research and Practice*, *16*(2), 393–407. https://doi.org/10.1039/c4rp00247d

Supasorn, S., & Promarak, V. (2015). Implementation of 5E inquiry incorporated with analogy learning approach to enhance conceptual understanding of chemical reaction rate for grade 11 students. *Chemistry Education Research and Practice*, *16*(1), 121–132. https://doi.org/10.1039/c4rp00190g

Supasorn, S., Wuttisela, K., Moonsarn, A., Khajornklin, P., Jarujamrus, P., & Chairam, S. (2022). GRADE-11 STUDENTS' CONCEPTUAL UNDERSTANDING OF CHEMICAL REACTION RATE FROM LEARNING BY USING THE SMALL-SCALE EXPERIMENTS. *Jurnal Pendidikan IPA Indonesia*, *11*(3), 433–448. https://doi.org/10.15294/jpii.v11i3.36535

Taber, K. S. (2013a). Three levels of chemistry educational research. In *Chemistry Education Research and Practice* (Vol. 14, Issue 2, pp. 151–155). https://doi.org/10.1039/c3rp90003g

Taber, K. S. (2013b). Three levels of chemistry educational research. In *Chemistry Education Research and Practice* (Vol. 14, Issue 2, pp. 151–155). https://doi.org/10.1039/c3rp90003g

Talib, O., Nawawi, M., Ali, W. Z. W., Mahmud, R., Putri, T. N., & Shariman, T. (2014). Implementing the SEA Application for Organic Chemistry: Arrow-Pushing versus Electron-Moving Techniques. *Information Technology Based Higher Education and Training*.

Taub, M., & Azevedo, R. (2018). Using Sequence Mining to Analyze Metacognitive Monitoring and Scientific Inquiry based on Levels of Efficiency and Emotions during Game-Based Learning. *Journal of Education Data Mining*, *10*(3).

Taub, M., Sawyer, R., Lester, J., & Azevedo, R. (2020). The Impact of Contextualized Emotions on Self-Regulated Learning and Scientific Reasoning during Learning with a Game-Based Learning Environment. *International Journal of Artificial Intelligence in Education*, *30*(1), 97–120. https://doi.org/10.1007/s40593-019-00191-1

Treagust, D. F., & Chittleborough, G. (2001). Chemistry: A matter of understanding representations. *Advances in Research on Teaching*, *8*, 239–267. https://doi.org/10.1016/s1479-3687(01)80029-8

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

Upahi, J. E., & Ramnarain, U. (2019). Representations of chemical phenomena in secondary school chemistry textbooks. *Chemistry Education Research and Practice*, *20*(1), 146–159. https://doi.org/10.1039/c8rp00191j

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). COMPUTER GAMING AND INTERACTIVE SIMULATIONS FOR LEARNING: A META-ANALYSIS. In *J. EDUCATIONAL COMPUTING RESEARCH* (Vol. 34, Issue 3).

Wahdan, W. Z., Sulistina, O., Sukarianingsih, D., & Kimia, J. (2017). ANALISIS KEMAMPUAN BERARGUMENTASI ILMIAH MATERI IKATAN KIMIA PESERTA DIDIK SMA, MAN, DAN PERGURUAN TINGGI TINGKAT I. In *Jurnal Pembelajaran Kimia OJS* (Vol. 2, Issue 2).

Wang, C. Y., & Barrow, L. H. (2011). Characteristics and Levels of Sophistication: An Analysis of Chemistry Students' Ability to Think with Mental Models. *Research in Science Education*, *41*(4), 561–586. https://doi.org/10.1007/s11165-010-9180-7

Wang, C.-Y. (2007a). *The Role of Mental-Modeling Ability, Content Knowledge, and Mental Models in General Chemistry Students' Understanding about Molecular Polarity* [Dissertation]. University of Missouri.

Wang, C.-Y. (2007b). *The role of mental-modeling ability, content knowledge, and mental models in general chemistry students' understanding about molecular polarity* [Dissertation]. University of Missouri.

Wang, M., & Zheng, X. (2021). Using Game-Based Learning to Support Learning Science: A Study with Middle School Students. *Asia-Pacific Education Researcher*, *30*(2), 167–176. https://doi.org/10.1007/s40299-020-00523-z

Wang, Y. (2022). Effects of augmented reality game-based learning on students' engagement. *International Journal of Science Education, Part B: Communication and Public Engagement*, *12*(3), 254–270. https://doi.org/10.1080/21548455.2022.2072015

Wasserman, J. A., & Banks, J. (2017). Details and Dynamics: Mental Models of Complex Systems in Game-Based Learning. *Simulation and Gaming*, *48*(5), 603–624. https://doi.org/10.1177/1046878117715056

Whitten, K. W., Davis, R. E., Peck, M. L., & Stanley, G. G. (2014). *Chemistry* (Vol. 10).

Wiji, W., & Mulyani, S. (2018a). Student's mental model, misconceptions, troublesome knowledge, and threshold concept on thermochemistry with DToM-POE. *Journal of Physics: Conference Series*, *1013*(1). https://doi.org/10.1088/1742-6596/1013/1/012098

Wiji, W., & Mulyani, S. (2018b). Student's mental model, misconceptions, troublesome knowledge, and threshold concept on thermochemistry with DToM-POE. *Journal of Physics: Conference Series*, *1013*(1). https://doi.org/10.1088/1742-6596/1013/1/012098

Wiji, W., Widhiyanti, T., Delisma, D., & Mulyani, S. (2021). THE INTERTEXTUALITY STUDY OF THE CONCEPTION, THRESHOLD CONCEPT, AND TROUBLESOME KNOWLEDGE ON REDOX REACTION. In *Journal of Engineering Science and Technology* (Vol. 16, Issue 2).

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. In *John Wiley & Sons, Inc. J Res Sci Teach* (Vol. 38, Issue 7).

Yalçinkaya, E., Taştan-Kirik, Ö., Boz, Y., & Yildiran, D. (2012). Is case-based learning an effective teaching strategy to challenge students' alternative conceptions regarding chemical kinetics? *Research in Science and Technological Education*, *30*(2), 151–172. https://doi.org/10.1080/02635143.2012.698605

Yang, J. C., Quadir, B., & Chen, N. S. (2016). Effects of the Badge Mechanism on Self-Efficacy and Learning Performance in a Game-Based English Learning Environment. In *Journal of Educational Computing Research* (Vol. 54, Issue 3, pp. 371–394). SAGE Publications Inc. https://doi.org/10.1177/0735633115620433

Yektyastuti, R., Ikhsan, J., & Sari, Rr. L. P. (2014, May 18). *The Development of Android Mobile Game as Senior High School Learning Media on Rate Reaction and Chemical Equilibrium*. www.merdeka.com

Yildirir, H. E., & Demirkol, H. (2018). IDENTIFYING MENTAL MODELS OF STUDENTS FOR PHYSICAL AND CHEMICAL CHANGE. *Journal of Baltic Science Education*, *17*(6).

Yu, Z., Gao, M., & Wang, L. (2021). The Effect of Educational Games on Learning Outcomes, Student Motivation, Engagement and Satisfaction. *Journal of Educational Computing Research*, *59*(3), 522–546. https://doi.org/10.1177/0735633120969214

Yustriani, A., & Zulfiani. (2023). Development of Android Based Educational Games as Learning Media on the Concept of Coordination System for Grade XI High School Students. *Jurnal Pendidikan Sains Indonesia*, *11*(3), 608–624. https://doi.org/10.24815/jpsi.v11i3.30656