PENGEMBANGAN ASESMEN FORMATIF GROVE-ALPHA UNTUK MELATIHKAN *SELF-REGULATED LEARNING* DAN *CONCEPTUAL-CHANGE* PADA MATERI HUKUM NEWTON

TESIS

Diajukan untuk Memenuhi Sebagian Syarat untuk Memperoleh Gelar magister Pendidikan Fisika

Disusun oleh:

Vania Valda

NIM 2308329

PROGRAM STUDI MAGISTER PENDIDIKAN FISIKA

FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM

UNIVERSITAS PENDIDIKAN INDONESIA

BANDUNG

2025

PENGEMBANGAN ASESMEN FORMATIF GROVE-ALPHA UNTUK MELATIHKAN *SELF-REGULATED LEARNING* DAN *CONCEPTUAL-CHANGE* PADA MATERI HUKUM NEWTON

LEMBAR HAK CIPTA

Oleh:
Vania Valda
NIM 2308329

S.Pd. Universitas Kristen Satya Wacana, 2023

Sebuah Tesis yang Diajukan untuk Memenuhi Salah Satu Syarat Memperoleh
Gelar Magister Pendidikan (M. Pd.) pada Program Studi Pendidikan Fisika

© Vania Valda 2025
Universitas Pendidikan Indonesia
Juni 2025

Hak cipta dilindungi Undang-Undang.
Tesis ini tidak boleh diperbanyak seluruhnya atau sebagian,
dengan dicetak ulang, difotocopy atau cara lainnya tanpa izin dari penulis.

LEMBAR PENGESAHAN TESIS

VANIA VALDA

2308329

PENGEMBANGAN ASESMEN FORMATIF GROVE-ALPHA UNTUK MELATIHKAN *SELF-REGULATED LEARNING* DAN *CONCEPTUAL-CHANGE* PADA MATERI HUKUM NEWTON

Disetujui dan disahkan oleh :

Pembimbing I

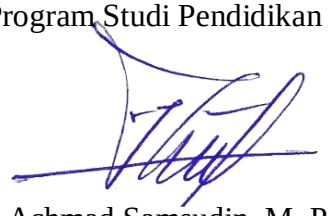
Irma Rahma Suwarma, Ph.D.
NIP. 198105032008012015

Pembimbing II

Prof. Dr. Endi Suhendi, M.Si
NIP. 197905012003121001

Mengetahui,

Ketua Program Studi Pendidikan Fisika



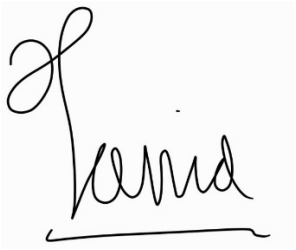
Dr. Achmad Samsudin, M. Pd.
NIP. 198310072008121004

PERNYATAAN

Dengan ini saya menyatakan bahwa tesis dengan judul "Pengembangan Asesmen Formatif GROVE_ALPHA untuk Melatihkan *Self-Regulated Learning* dan *Conceptual-Change* pada Materi Hukum Newton SMA" ini beserta seluruh isinya adalah benar-benar karya saya sendiri. 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/sanksi apabila di kemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya saya ini.

Bandung, 6 Agustus 2025

Saya yang menyatakan,



Vania Valda

NIM. 2308329

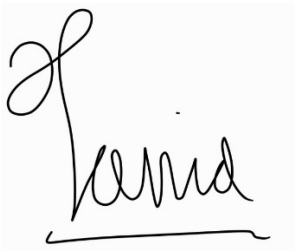
KATA PENGANTAR

Puji syukur penulis panjatkan ke hadirat Tuhan Yang Maha Esa atas segala rahmat, karunia, dan pertolongan-Nya sehingga tesis yang berjudul *"Pengembangan Asesmen Formatif GROVE-ALPHA untuk Melatihkan Self-Regulated Learning dan Conceptual Change pada Materi Hukum Newton SMA"* ini dapat diselesaikan dengan baik.

Tesis ini disusun untuk memenuhi salah satu syarat memperoleh gelar Magister Pendidikan pada Program Studi Pendidikan Fisika, Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia. Penulis menyadari bahwa penyelesaian tesis ini tidak terlepas dari bantuan, dukungan, serta bimbingan dari berbagai pihak. Oleh karena itu, penulis menyampaikan penghargaan dan terima kasih yang tulus kepada semua pihak yang telah membantu, baik secara langsung maupun tidak langsung, dalam proses penyusunan tesis ini.

Penulis menyadari bahwa tesis ini masih jauh dari kesempurnaan. Oleh karena itu, penulis mengharapkan kritik dan saran yang membangun dari pembaca. Semoga tesis ini bermanfaat khususnya bagi penulis dan umumnya bagi pembaca.

Bandung, 6 Agustus 2025



Vania Valda

NIM: 2308329

UCAPAN TERIMA KASIH

Pada kesempatan ini, penulis menyampaikan terima kasih yang sebesar-besarnya kepada:

1. Ibu Irma Rahma Suwarma, Ph.D., selaku Pembimbing I, atas arahan, bimbingan, dan motivasi yang diberikan sejak tahap awal penelitian hingga penyusunan tesis ini.
2. Bapak Prof. Dr. Endi Suhendi, M.Si., selaku Pembimbing II, atas masukan konstruktif dan dorongan yang sangat membantu penyempurnaan penelitian ini.
3. Bapak Dr. Achmad Samsudin, M.Pd., selaku Ketua Program Studi Pendidikan Fisika, beserta seluruh dosen dan staf Program Studi Magister Pendidikan Fisika UPI atas ilmu, dukungan akademik, dan bantuan administrasi selama masa studi.
4. Sekolah Santa Maria 3 Cimahi, beserta kepala sekolah, guru fisika, dan peserta didik yang telah menjadi subjek penelitian serta mendukung penuh proses pengambilan data.
5. Rekan-rekan seangkatan: Teh Sumiati, Beta, Bu Entang, Teh Santri, Teh Farika, Teh Andeh, Kang Alvin, Kang Zain, dan Kang Iky, atas dukungan dan semangat yang diberikan selama masa studi.
6. Ko Jovi, pasangan yang senantiasa memberikan ide segar, masukan berharga, dukungan tanpa henti, serta menjadi sumber semangat utama.
7. Keluarga tercinta, atas doa, dukungan, dan pengingat yang tiada henti sepanjang perjalanan studi ini.
8. Seluruh pihak lain yang tidak dapat disebutkan satu per satu atas bantuan langsung maupun tidak langsung dalam penyelesaian tesis ini.

Penulis berharap karya ini dapat memberikan kontribusi positif bagi pengembangan asesmen formatif, inovasi pembelajaran berbasis teknologi, dan peningkatan kualitas pendidikan fisika di Indonesia.

Bandung, 6 Agustus 2025

Vania Valda

NIM: 2308329

PENGEMBANGAN ASESMEN FORMATIF GROVE-ALPHA UNTUK MELATIHKAN *SELF-REGULATED LEARNING* DAN *CONCEPTUAL-CHANGE* PADA MATERI HUKUM NEWTON

ABSTRAK

Penelitian ini bertujuan untuk mengembangkan *Gamified Reward-Based Online Formative Assessment for Learning Physics with Artificial Intelligence* (GROVE-ALPHA) sebagai inovasi asesmen formatif untuk melatihkan *self-regulated learning* (SRL) dan *conceptual change* pada materi Hukum Newton di SMA. Penelitian menggunakan metode *mixed methods* dengan desain eksplorasi sekuensial yang melibatkan pengumpulan data kualitatif pada tahap awal, diikuti dengan pengumpulan data kuantitatif pada dua tahap berikutnya. Instrumen penelitian meliputi asesmen formatif berbasis gamifikasi dengan integrasi AI, *Motivated Strategies for Learning Questionnaire* (MSLQ), dan rubrik penilaian *conceptual change*. Validasi instrumen dilakukan oleh ahli dan peserta didik untuk menilai aspek konten dan konstruksi. Hasil penelitian menunjukkan bahwa GROVE-ALPHA memiliki tingkat validitas yang tinggi secara konten dan konstruksi. Penggunaan GROVE-ALPHA berdampak positif terhadap peningkatan SRL, yang terlihat dari kenaikan skor motivasi dan strategi belajar peserta didik pada instrumen MSLQ. Selain itu, terjadi peningkatan signifikan dalam *conceptual change*, dengan mayoritas peserta didik mengalami pergeseran pemahaman ke arah konsep ilmiah yang benar. Wawancara mendalam mengungkapkan bahwa peserta didik merasakan keterlibatan belajar yang lebih tinggi, terbantu dalam memonitor pemahaman mereka, serta lebih termotivasi untuk memperbaiki kesalahan konsep. Kesimpulannya, GROVE-ALPHA efektif digunakan sebagai asesmen formatif berbasis gamifikasi dan AI yang mampu memfasilitasi peningkatan SRL sekaligus memperbaiki miskonsepsi peserta didik pada materi Hukum Newton. Inovasi ini berpotensi diimplementasikan lebih luas sebagai bagian integral dari pembelajaran fisika interaktif dan adaptif.

Kata kunci: asesmen formatif, gamifikasi, kecerdasan buatan, *self-regulated learning*, *conceptual change*, Hukum Newton

ABSTRACT

This study aims to develop the *Gamified Reward-Based Online Formative Assessment for Learning Physics with Artificial Intelligence* (GROVE-ALPHA) as an innovative formative assessment tool to foster *self-regulated learning* (SRL) and *conceptual change* in Newton's Laws topics at the senior high school level. A mixed-methods approach with a sequential exploratory design was employed, beginning with qualitative data collection, followed by two stages of quantitative data collection. Research instruments included a gamified formative assessment integrated with AI, the *Motivated Strategies for Learning Questionnaire* (MSLQ), and a *conceptual change* assessment rubric. Instrument validation was conducted by experts and students to evaluate both content and construct aspects. The findings indicate that GROVE-ALPHA achieved high validity in both content and construct. Its implementation positively impacted SRL, as evidenced by increased motivation and learning strategy scores on the MSLQ. Moreover, a significant improvement in *conceptual change* was observed, with most students shifting their understanding toward scientifically accurate concepts. In-depth interviews revealed that students experienced higher learning engagement, improved self-monitoring of their understanding, and greater motivation to correct conceptual errors. In conclusion, GROVE-ALPHA is effective as a gamified, AI-integrated formative assessment tool that can enhance SRL and address students' misconceptions in Newton's Laws. This innovation holds potential for broader implementation as an integral part of interactive and adaptive physics learning.

Keywords: formative assessment, gamification, artificial intelligence, *self-regulated learning*, *conceptual change*, Newton's Laws

DAFTAR ISI.

DAFTAR TABEL

DAFTAR GAMBAR

DAFTAR LAMPIRAN

DAFTAR PUSTAKA

Arikunto, S. (2021). *Dasar-Dasar Evaluasi Pendidikan Edisi 3* (3 ed.). Bumi Aksara.

Artino, A. R., & Stephens, J. M. (2009). Academic motivation and self-regulation: A comparative analysis of undergraduate and graduate students learning online. *The Internet and Higher Education*, *12*(3–4), 146–151. https://doi.org/10.1016/j.iheduc.2009.02.001

Azevedo, R., Johnson, A., Chauncey, A., & Burkett, C. (2010). Self-regulated Learning with MetaTutor: Advancing the Science of Learning with MetaCognitive Tools. *New Science of Learning*, 225–247. https://doi.org/10.1007/978-1-4419-5716-0_11

Black, P., & Wiliam, D. (1998). Assessment and Classroom Learning. *Assessment in Education: Principles, Policy & Practice*, *5*(1), 7–74. https://doi.org/10.1080/0969595980050102

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31. https://doi.org/10.1007/s11092-008-9068-5

Budiyono, S., & Haerullah, H. (2024). Dampak Teknologi terhadap Pembelajaran di Abad 21. *TSAQOFAH*, *4*(3), 1790–1800. https://doi.org/10.58578/tsaqofah.v4i3.3005

Cebesoy, Ü. B. (2013). *Pre-Service Science Teachers' Perceptions of Self-Regulated Learning in Physics*. *2*(1).

Chan, C. K. Y., & Tsi, L. H. Y. (2023). *The AI Revolution in Education: Will AI Replace or Assist Teachers in Higher Education?* https://doi.org/10.48550/ARXIV.2305.01185

Chan, K. T. (2021). Embedding Formative Assessment in Blended Learning Environment: The Case of Secondary Chinese Language Teaching in Singapore. *Education Sciences, 11*(7), 360. https://doi.org/10.3390/educsci11070360

Chi, M. T. H. (2009). Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science, 1*(1), 73–105. https://doi.org/10.1111/j.1756-8765.2008.01005.x

Chng, L. S., & Lund, J. (2018). Assessment for Learning in Physical Education: The What, Why and How. *Journal of Physical Education, Recreation & Dance, 89*(8), 29–34. https://doi.org/10.1080/07303084.2018.1503119

Cook, D. A., Thompson, W. G., & Thomas, K. G. (2011). The Motivated Strategies for Learning Questionnaire: Score validity among medicine residents: Score validity of the MSLQ. *Medical Education, 45*(12), 1230–1240. https://doi.org/10.1111/j.1365-2923.2011.04077.x

Council, N. R. (2001). *Knowing What Students Know: The Science and Design of Educational Assessment* (J. W. Pellegrino, N. Chudowsky, & R. Glaser, Ed.). The National Academies Press. https://doi.org/10.17226/10019

Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and conducting mixed methods research* (Third Edition). SAGE.

Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). From game design elements to gamefulness: Defining "gamification." *Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments*, 9–15. https://doi.org/10.1145/2181037.2181040

D'mello, S., & Graesser, A. (2012). AutoTutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. *ACM Transactions on Interactive Intelligent Systems*, *2*(4), 1–39. https://doi.org/10.1145/2395123.2395128

Dr. Usman, T., & Danjuma, A. (2025). *Item Psychometric Properties and Students' Academic Performance: An Analysis of 2022 Mathematics Placement Examinations in Hadejia Town, Jigawa State*. https://doi.org/10.5281/ZENODO.14742649

Fauziah, N. A. (2018). *Identifikasi Miskonsepsi Menggunakan Tes Dignostik Four-Tier pada Hukum Newton dan Penerapannya di MAN 1 Kota Bogor* [UIN Syarif Hidayatullah]. https://repository.uinjkt.ac.id/dspace/handle/123456789/61368

Fuller, J. S., & Dawson, K. M. (2017). Student Response Systems for Formative Assessment: Literature-based Strategies and Findings from a Middle School Implementation. *Contemporary Educational Technology*, *8*(4). https://doi.org/10.30935/cedtech/6206

Gaurina, M., Alajbeg, A., & Weber, I. (2025). The Power of Play: Investigating the Effects of Gamification on Motivation and Engagement in Physics

Classroom. *Education Sciences*, *15*(1), 104. https://doi.org/10.3390/educsci15010104

Giancoli, D. C. (2005). *Physics: Principles with Applications* (6th ed.). Pearson Education.

Gikandi, J. W., Morrow, D., & Davis, N. E. (2011). Online formative assessment in higher education: A review of the literature. *Computers & Education*, *57*(4), 2333–2351. https://doi.org/10.1016/j.compedu.2011.06.004

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74. https://doi.org/10.1119/1.18809

Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of Physics* (10th ed.). Wiley.

Hamari, J., Koivisto, J., & Sarsa, H. (2014). Does Gamification Work? -- A Literature Review of Empirical Studies on Gamification. *2014 47th Hawaii International Conference on System Sciences*, 3025–3034. https://doi.org/10.1109/hicss.2014.377

Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force concept inventory. *The Physics Teacher*, *30*(3), 141–158.

Huda, S., Hartono, & Masturi. (2020). The development of authentic scientific inquiry assessment to measure the laboratory skills. *Journal of Physics: Conference Series*, *1567*(2), 022071. https://doi.org/10.1088/1742-6596/1567/2/022071

Iman, N., Ramli, M., & Saridewi, N. (2021). Kahoot as an Assessment Tools: Students' Perception of Game-based Learning Platform. *Jurnal Penelitian dan Pembelajaran IPA, 7*(2), 245. https://doi.org/10.30870/jppi.v7i2.8304

Kaledio, P., Robert, A., & Frank, L. (2024). The Impact of Artificial Intelligence on Students' Learning Experience. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4716747

Kalogiannakis, M., Papadakis, S., & Zourmpakis, A.-I. (2021). Gamification in Science Education. A Systematic Review of the Literature. *Education Sciences*, *11*(1), 22. https://doi.org/10.3390/educsci11010022

Kamalov, F., Santandreu Calonge, D., & Gurrib, I. (2023). New Era of Artificial Intelligence in Education: Towards a Sustainable Multifaceted Revolution. *Sustainability*, *15*(16), 12451. https://doi.org/10.3390/su151612451

Kapur, M. (2008). Productive Failure. *Cognition and Instruction, 26*(3), 379–424. https://doi.org/10.1080/07370000802212669

Kemendikbudristek. (2022). *Kurikulum Merdeka: Capaian Pembelajaran SMA*.

Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi. (2022). *Salinan SK Kepala Badan tentang Perubahan SK 008 tentang Capaian Pembelajaran*. Badan Standar, Kurikulum, dan Asesmen Pendidikan. https://kurikulum.kemdikbud.go.id/wp-content/uploads/2022/06/033_H_KR_2022-Salinan-SK-Kabadan-tentang-Perubahan-SK-008-tentang-Capaian-Pembelajaran.pdf

Khan, G. (2015). Using Item analysis on essay types questions given in summative examination of medical college students: Facility value, Discrimination

index. *International Journal of Research in Medical Sciences*, 1. https://doi.org/10.5455/2320-6012.ijrms20150131

Kusairi, S. (2020). A web-based formative feedback system using isomorphic items to support Physics learning. *Journal of Technology and Science Education*, *10*(1), 117. https://doi.org/10.3926/jotse.781

Kwarikunda, D., Schiefele, U., Ssenyonga, J., & Muwonge, C. M. (2021). Secondary School Students' Motivation Profiles for Physics Learning: Relations with Cognitive Learning Strategies, Gender, Attitudes and Individual Interest. *African Journal of Research in Mathematics, Science and Technology Education*, *25*(2), 197–210. https://doi.org/10.1080/18117295.2021.1956720

Lai, K. -W., Khaddage, F., & Knezek, G. (2013). Blending student technology experiences in formal and informal learning. *Journal of Computer Assisted Learning*, *29*(5), 414–425. https://doi.org/10.1111/jcal.12030

Li, Y., & Singh, C. (2023). Impact of perceived recognition by physics instructors on women's self-efficacy and interest. *Physical Review Physics Education Research*, *19*(2). https://doi.org/10.1103/physrevphyseducres.19.020125

Limón, M. (2001). On the cognitive conflict as an instructional strategy for conceptual change: A critical appraisal. *Learning and Instruction*, *11*(4–5), 357–380. https://doi.org/10.1016/s0959-4752(00)00037-2

Luckin, R., Holmes, W., & Forcier, L. B. (2016). An argument for AI in Education. *Pearson*.

McDermott, L. C., Shaffer, P. S., & Rosenquist, M. L. (2001). *Physics by Inquiry*. Wiley.

Mitchell-Polka, K., Lindsay, W. E., Martins, J. S., & Otero, V. K. (2020). The physics classroom as a space for empowerment. *2020 Physics Education Research Conference Proceedings*, 340–345. https://doi.org/10.1119/perc.2020.pr.mitchell-polka

Nadhifah, I. N., Adila, A. S. D., & Lestari, A. (2023). Description of Comprehension, Perceptions, and Challenges of Science Teachers' Formative Assessment Practice in Wonosobo. *PENDIPA Journal of Science Education*, *7*(1), 14–23. https://doi.org/10.33369/pendipa.7.1.14-23

Nicol, D. J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, *31*(2), 199–218. https://doi.org/10.1080/03075070600572090

Paz-Baruch, N., & Hazema, H. (2023). Self-Regulated Learning and Motivation Among Gifted and High-Achieving Students in Science, Technology, Engineering, and Mathematics Disciplines: Examining Differences Between Students From Diverse Socioeconomic Levels. *Journal for the Education of the Gifted*, *46*(1), 34–76. https://doi.org/10.1177/01623532221143825

Pechenkina, E., Laurence, D., Oates, G., Eldridge, D., & Hunter, D. (2017). Using a gamified mobile app to increase student engagement, retention and

academic achievement. *International Journal of Educational Technology in Higher Education*, *14*(1). https://doi.org/10.1186/s41239-017-0069-7

Piaget, J. (1971). *Biology and knowledge: An essay on the relations between organic regulations and cognitive processes*. Univ. of Chicago Pr.

Pintrich, P. R. (2000). The Role of Goal Orientation in Self-Regulated Learning. Dalam *Handbook of Self-Regulation* (hlm. 451–502). Elsevier. https://doi.org/10.1016/b978-012109890-2/50043-3

Pintrich, P. R., David A. F. Smith, Teresa Garcia, & Wilbert J. McKeachie. (1991). *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ)* (91-8-004 NCRIPTAL-91-B-004). National Center for Research to Improve Postsecondary Teaching and Learning, Ann Arbor, MI. https://files.eric.ed.gov/fulltext/ED338122.pdf

Pintrich, P. R., & De Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33–40. https://doi.org/10.1037/0022-0663.82.1.33

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982a). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Posner, G. J., Strike, K. A., Hewson, P. W., & Gertzog, W. A. (1982b). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science Education*, *66*(2), 211–227. https://doi.org/10.1002/sce.3730660207

Putri, A. H., Samsudin, A., & Suhandi, A. (2022). Exhaustive studies before covid-19 pandemic attack of students' conceptual change in science education: A literature review. *Journal of Turkish Science Education*, *19*(3), 808–829. https://doi.org/10.36681/tused.2022.151

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., Kyza, E., Edelson, D., & Soloway, E. (2004). A Scaffolding Design Framework for Software to Support Science Inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386. https://doi.org/10.1207/s15327809jls1303_4

Redecker, C., & Johannessen, Ø. (2013). Changing Assessment—Towards a New Assessment Paradigm Using ICT. *European Journal of Education*, *48*(1), 79–96. https://doi.org/10.1111/ejed.12018

Rodríguez-Ardura, I., & Meseguer-Artola, A. (2016). What leads people to keep on e-learning? An empirical analysis of users' experiences and their effects on continuance intention. *Interactive Learning Environments*, *24*(6), 1030–1053. https://doi.org/10.1080/10494820.2014.926275

Rojas, S. (2009). *On the teaching and learning of physics: A Criticism and a Systemic Approach* (arXiv:0902.1151). arXiv. https://doi.org/10.48550/arXiv.0902.1151

Rožman, M., Tominc, P., & Vrečko, I. (2023). Building skills for the future of work: Students' perspectives on emerging jobs in the Data and AI Cluster through artificial intelligence in education. *Environment and Social Psychology*, *8*(2). https://doi.org/10.54517/esp.v8i2.1670

Samsudin, A., Zulfikar, A., Saepuzaman, D., Suhandi, A., Aminudin, A. H., Supriyadi, S., & Coştu, B. (2024). Correcting grade 11 students' misconceptions of the concept of force through the conceptual change model (CCM) with PDEODE*E tasks. *Journal of Turkish Science Education*, *21*(2), 212–231. https://doi.org/10.36681/tused.2024.012

Sari, M. W. N., & Airlanda, G. S. (2022). Pengembangan E-book dengan Strategi Problem Based Learning dalam Berpikir Kritis dan Kreatif. *EDUKATIF : JURNAL ILMU PENDIDIKAN*, *4*(4), 5845–5851. https://doi.org/10.31004/edukatif.v4i4.3232

Serway, R. A., & Jewett, J. W. (2018). *Physics for Scientists and Engineers* (10th ed.). Cengage Learning.

Shalini, & Tewari, A. (2020). Sustainable Education in India through Artificial Intelligence: Challenges and Opportunities. *12th ACM Conference on Web Science Companion*, 41–47. https://doi.org/10.1145/3394332.3402828

Sudiyono, Kurniawati, M., & Nugraha, D. A. (2021). The Role Self-Regulated Learning on Project-Based Learning to Natural Science Learning Outcome. *Advances in Social Science, Education and Humanities Research*. 5th Asian Education Symposium 2020 (AES 2020), Bandung, Indonesia. https://doi.org/10.2991/assehr.k.210715.056

Teckwani, S. H., Wong, A. H.-P., Luke, N. V., & Low, I. C. C. (2024). Accuracy and reliability of large language models in assessing learning outcomes achievement across cognitive domains. *Advances in Physiology Education*, *48*(4), 904–914. https://doi.org/10.1152/advan.00137.2024

Tipler, P. A., & Mosca, G. (2008). *Physics for Scientists and Engineers* (6th ed.). W. H. Freeman.

Tolentino, A. N., & Roleda, L. S. (2019). Gamified physics instruction in a reformatory classroom context. *Proceedings of the 10th International Conference on E-Education, E-Business, E-Management and E-Learning*, 135–140. https://doi.org/10.1145/3306500.3306527

Treagust, D. F., & Duit, R. (2008). Conceptual change: A discussion of theoretical, methodological and practical challenges for science education. *Cultural Studies of Science Education*, *3*(2), 297–328. https://doi.org/10.1007/s11422-008-9090-4

Van De Pol, J., Volman, M., & Beishuizen, J. (2010). Scaffolding in Teacher–Student Interaction: A Decade of Research. *Educational Psychology Review, 22*(3), 271–296. https://doi.org/10.1007/s10648-010-9127-6

Vieriu, A. M., & Petrea, G. (2025). The Impact of Artificial Intelligence (AI) on Students' Academic Development. *Education Sciences*, *15*(3), 343. https://doi.org/10.3390/educsci15030343

Vygotsky, L. S. (1980). *Mind in Society: Development of Higher Psychological Processes* (M. Cole, V. Jolm-Steiner, S. Scribner, & E. Souberman, Ed.). Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

Wu, M. L., Zhou, Y., & Li, L. (2023). The effects of a gamified online course on pre-service teachers' confidence, intention, and motivation in integrating technology into teaching. *Education and Information Technologies, 28*(10), 12903–12918. https://doi.org/10.1007/s10639-023-11727-3

Xu, H., Ge, S., & Yuan, F. (2022). Research on the Mechanism of Influence of Game Competition Mode on Online Learning Performance. *Behavioral Sciences*, *12*(7), 225. https://doi.org/10.3390/bs12070225

Yavich, R. (2025). Will the Use of AI Undermine Students Independent Thinking? *Education Sciences*, *15*(6), 669. https://doi.org/10.3390/educsci15060669

Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, *41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2

Zuo, M., Kong, S., Ma, Y., Hu, Y., & Xiao, M. (2023). The Effects of Using Scaffolding in Online Learning: A Meta-Analysis. *Education Sciences*, *13*(7), 705. https://doi.org/10.3390/educsci13070705