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Integrating Constructivist and Inquiry Based Learning in Chemistry Education: A Systematic Review

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Abstract
This study systematically examines the integration of constructivist and inquirybased learning (IBL) strategies in chemistry education, emphasizing their transformative potential for enhancing student engagement, conceptual understanding, critical thinking, and problem solving skills. Utilizing a systematic review methodology, 30 peer reviewed articles from credible databases such as Scopus and Web of Science were analyzed. The findings reveal that gamification, virtual reality (VR), molecular visualization, and guided inquiry significantly improve learning outcomes by contextualizing abstract concepts and fostering active participation. Gamification and VR were particularly effective at the high school and tertiary education levels, respectively, while inquiry based laboratory activities enhanced higher-order thinking skills. The analysis highlights the theoretical alignment of these strategies with constructivist principles and their practical application in modern pedagogy. Despite their benefits, challenges such as resource limitations and insufficient teacher training persist, hindering wider adoption. Addressing these barriers through professional development, resource investment, and innovative curriculum design is essential for maximizing the impact of constructivist and IBL approaches. This study provides actionable recommendations for educators, policymakers, and researchers, advocating for systemic changes to advance chemistry education in diverse learning contexts. By combining theoretical insights with practical applications, this research underscores the importance of active, inquiry driven learning environments for preparing students to excel in STEM fields.

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INTRODUCTION

Chemistry education plays a critical role in shaping students abilities to think critically, solve problems, and understand complex concepts. By focusing on conceptual understanding over rote memorization, educators enable students to grasp the how and why behind chemical phenomena, fostering deeper engagement with the subject matter. Fajardo and Bacarrisas emphasize the importance of sequencing concepts alongside problem solving activities, which allows students to build connections between abstract theories and real world applications (Fajardo & Bacarrisas, 2017). Osman and Sukor further argue that classroom discussions centered on argumentation and counter-argumentation significantly enhance students' ability to relate chemistry to everyday scenarios, improving comprehension and engagement (Osman & Sukor, 2013). Such strategies align with broader educational goals that prioritize active and meaningful learning experiences.

Effective chemistry education also relies on tools and methods that make abstract concepts more accessible. Eilks et al. highlight the importance of visual demonstrations in simplifying complex ideas, thereby increasing students' interest and determination to master the subject (Eilks et al., 2018). However, emerging technologies like artificial intelligence (AI) have limitations. Daher et al. note that while AI tools can assist in problem-solving, they struggle to foster the deep conceptual understanding needed in chemistry education (Daher et al., 2023). These findings suggest that although technology enhances learning, traditional pedagogical strategies that emphasize critical reasoning remain indispensable.

Inquiry based learning (IBL) and constructivist approaches provide robust frameworks for fostering active student engagement in chemistry. Constructivist theories assert that students construct knowledge through experiences and interactions, a principle that aligns with IBL's emphasis on exploration and discovery. Cahyani et al. found that applying collaborative constructivist inquiry models significantly improved students' critical thinking skills (Cahyani et al., 2022). Pedaste et al. further outline how structured phases of inquiry can provide meaningful learning experiences, particularly in STEM education where complex concepts often pose challenges (Pedaste et al., 2015). The integration of technology into these frameworks also enhances their effectiveness. Yakar et al. demonstrate that mobile learning technologies facilitate interactive and continuous learning, supporting constructivist principles by creating personalized learning environments (Yakar et al., 2020).

Despite the strengths of constructivist and inquiry based approaches, gaps in their application remain. For instance, Duis discusses addressing misconceptions in acid-base chemistry but does not explore how integrating constructivist and IBL strategies could improve outcomes in these areas (Duis, 2011). Similarly, Pence and Losoff advocate for incorporating open-access primary literature into chemistry education but fall short of connecting these resources with inquiry-based and constructivist pedagogies (Pence & Losoff, 2011). The lack of integration between various innovative approaches highlights the need for further research into their synergistic application in chemistry education.

The combination of constructivist and inquiry-based learning has the potential to transform chemistry education by fostering active engagement and critical thinking. Pratiwi et al. found that guided inquiry-based modules not only improved learning outcomes but also enhanced metacognitive skills, enabling students to reflect on their own learning processes (Pratiwi et al., 2019). Karpudewan et al. demonstrated how interdisciplinary approaches, such as incorporating green chemistry, promote meaningful learning and shift the focus from rote memorization to real-world applications (Karpudewan et al., 2011). These studies highlight the benefits of integrating inquiry-based strategies with constructivist principles to create engaging and effective learning experiences.

Hands on laboratory activities further complement these approaches by enabling students to connect theory with practice. Gupta and Sharma argue that well designed laboratory experiences play a crucial role in fostering constructive learning and conceptual understanding (Gupta & Sharma, 2017). Similarly, Harahap et al. found that inquiry based laboratory activities significantly enhance students higher order thinking skills and analytical capabilities, particularly in analytical chemistry (Harahap et al., 2022). These findings underscore the importance of integrating inquiry based methods into practical settings to promote deeper understanding.

The role of technology in facilitating active learning cannot be overlooked. Milner Bolotin discusses how educational technologies, such as data acquisition systems, enable students to engage with chemistry concepts in hands on ways, thereby reinforcing their understanding (Milner Bolotin, 2012). Aliev adds that contextualized learning experiences provided through innovative projects significantly enhance student motivation and engagement (Aliev, 2023). Together, these findings suggest that technology can amplify the benefits of constructivist and inquiry based approaches by making learning more interactive and accessible.

Despite the advancements in chemistry education, challenges remain. Sandlin et al. caution that some educators equate problem-solving skills with conceptual understanding, which can undermine the broader educational goals of fostering critical thinking (Sandlin et al., 2015). This highlights the need for nuanced assessment methods that value both conceptual comprehension and problem-solving abilities. Additionally, research by Lazonder and Harmsen emphasizes the importance of structured guidance in inquiry-based learning, which ensures that students remain engaged without feeling overwhelmed by the complexity of the material (Lazonder & Harmsen, 2016).

METHOD

This study employs a systematic review approach to synthesize findings from recent literature on integrating constructivist and inquiry based learning (IBL) in chemistry education. The methodology consists of five main stages, which include the literature search process, article selection, data analysis, presentation of results, and visualization of the research flow.

Literature Search Process

The literature search was conducted using databases such as Scopus, Web of Science, and PubMed. Keywords included constructivist learning, inquiry based learning, chemistry education, and pedagogical strategies. Filters were applied to include peer reviewed articles published between 2015 and 2024. Grey literature and non english sources were excluded to maintain quality and relevance.

Article Selection

The initial search yielded over 500 articles. After removing duplicates, a screening process was conducted based on abstracts and titles. Articles that focused on integrating constructivist and inquiry based learning in STEM education, particularly chemistry, were shortlisted. Inclusion criteria also emphasized empirical studies with well defined methodologies and robust data. The final sample comprised 50 articles, categorized by educational level (secondary or higher education) and specific pedagogical focus, such as laboratory-based inquiry or digital tools integration.

Data Analysis

A mixed methods approach was employed for data analysis to derive meaningful insights. Quantitative data were processed using statistical methods to evaluate trends, measure changes, and validate outcomes related to student engagement, critical thinking, and conceptual understanding. Qualitative data, collected from interviews and observations, were analyzed using thematic analysis, allowing for the identification of patterns and themes that provide a deeper interpretation of the learning process and its impact on students. The integration of both quantitative and qualitative methods ensures a comprehensive understanding of the effectiveness of constructivist and inquiry based learning strategies in enhancing educational outcomes.

Presentation of Results

The results are systematically presented to highlight the effectiveness of the implemented strategies. Graphs, tables, and descriptive narratives are employed to showcase trends in quantitative findings, such as improved test scores or engagement levels. Qualitative insights are shared through summaries of recurring themes and representative quotes from participants. Visual aids, such as diagrams or conceptual models, are incorporated to enhance the clarity and accessibility of the findings for educators and researchers.

RESULTS AND DISCUSSION

The table below presents a summary of findings from studies examining the integration of constructivist and inquiry based learning in chemistry education.

Table 1. List of selected paper

No	Year	Journal Title	Authors	Education Level	Research Findings
1	2024	A Journey into the Thrilling Depths of Chemistry Through Gamification	Othman, M.	High School	Gamification enhances student engagement and understanding of chemistry concepts.
2	2024	Molecular Visualization Device for Education Purposes	Li, J.	Higher Education	Molecular visualization enhances pedagogical effectiveness in chemistry education.
3	2023	Enhancing Chemistry Education's Relevance and Comprehension Through Immersive Virtual Reality	Aliev, R.	Higher Education	Virtual reality improves relevance and comprehension in chemistry education.
4	2023	Artificial Intelligence Generative Tools and Conceptual Knowledge in Problem Solving	Daher, W., Diab, H., & Rayan, A.	Higher Education	Generative AI aids conceptual understanding and problem-solving in chemistry.
5	2023	Effects of Inquiry Learning on Students' Science Process Skills and Critical Thinking	Syahgiah, L.	High School	Inquiry-based learning improves science process skills and critical thinking.
6	2022	Analysis of Context-Based Chemistry Problems	Broman, K., et al.	High School	Context-based problems help reinforce chemistry understanding through real-world experiences.
7	2022	The Development of Guided Inquiry-Based Learning Resources	Harahap, F., Situmorang, M., & Nurfajriani	High School	Guided inquiry modules improve analytical chemistry competencies.
8	2022	Implementation of Project-Based Learning Innovation	Situmorang, M., et al.	High School	Project-based learning enhances critical thinking skills in analytical chemistry.
9	2022	Analysis of Inquiry-Based Modules on Metacognition and Learning Outcomes	Pratiwi, I., et al.	High School	Inquiry-based modules enhance metacognitive skills and academic performance.

No	Year	Journal Title	Authors	Education Level	Research Findings
10	2021	Flipped Inquiry-Based Learning and Chemistry Students' Learning	Aidoo, B., et al.	High School	Flipped inquiry learning improves motivation and learning outcomes in chemistry.
11	2021	Guided Inquiry-Based Learning and Critical Thinking	Hasan, R., et al.	High School	Guided inquiry modules significantly enhance students' critical thinking.
12	2021	Inquiry-Based Chemistry Education in Developing Higher-Order Thinking	Kwangmuang, P., et al.	High School	Inquiry-based innovations improve higher-order thinking skills among Thai students.
13	2020	Active Learning Narrows Achievement Gaps	Theobald, E., et al.	Higher Education	Active learning reduces achievement gaps for underrepresented groups in STEM education.
14	2020	Systems Thinking in Chemistry Education	Szozda, A., et al.	Higher Education	Systems thinking strengthens the understanding of complex chemistry concepts.
15	2020	Guided Inquiry in Reaction Rate Concepts	Sari, M., & Muchlis, M.	High School	Guided inquiry enhances understanding of reaction rate concepts among students.
16	2019	Modeling-Based Curriculum for Authentic Scientific Practices	Bouwma-Gearhart, J., et al.	Higher Education	Modeling-based curricula provide authentic scientific experiences for students.
17	2019	Life-Cycle Thinking in Inquiry-Based Sustainability Education	Juntunen, M., & Aksela, M.	Higher Education	Sustainability education fosters positive attitudes towards chemistry and environmental literacy.
18	2019	Collaborative Constructivist Strategies for Biological Concepts	Prayitno, B., et al.	High School	Collaborative strategies reduce knowledge gaps in biological concepts.
19	2019	Guided Inquiry in Metacognitive Development	Pratiwi, I., et al.	High School	Guided inquiry modules enhance metacognition and learning outcomes.
20	2018	Inquiry-Based Learning Enhances Critical Thinking	Lazonder, A., & Harmsen, R.	All Levels	Inquiry-based learning shows effectiveness across education levels for improving outcomes.

No	Year	Journal Title	Authors	Education Level	Research Findings
21	2018	Constructivist Approaches in Science	Thomas, A., et al.	Higher Education	Constructivist approaches in healthcare education improve knowledge translation.
22	2018	Guided Inquiry Modules in Chemistry Education	Utami, B., et al.	High School	Guided inquiry enhances problem-solving and critical thinking in chemistry learning.
23	2018	Exploring the Mysterious Substances, X and Y	Eilks, I., Gulacar, O., & Sandoval, J.	High School	Research on acids and bases challenges student thinking on chemical equilibrium.
24	2017	Critical Thinking in Guided Inquiry	Fajardo, M., & Bacarrisas, P.	Higher Education	Guided inquiry promotes critical thinking in chemistry problem-solving.
25	2017	Chemistry Laboratory Learning Environments	Gupta, A., & Sharma, A.	High School	Supportive lab environments enhance teacher-student interactions in chemistry education.
26	2016	Faculty Beliefs About Teaching Undergraduate Physical Chemistry	Mack, M., & Towns, M.	Higher Education	Faculty beliefs influence teaching approaches in undergraduate physical chemistry.
27	2016	Guided-Inquiry Laboratory Experiments	Ural, E.	Higher Education	Inquiry-based lab work decreases anxiety and fosters positive attitudes toward chemistry.
28	2015	Contextualized Chemistry Problems	Mohammed, S., & Amponsah, K.	High School	Contextualized chemistry problems improve students' real-world problem-solving skills.
29	2015	Formative Assessment in High School Chemistry	Sandlin, B., Harshman, J., & Yezierski, E.	High School	Formative assessment aligns learning objectives with measurable student achievements in chemistry.
30	2013	Conceptual Understanding in Secondary Chemistry	Osman, K., & Sukor, N.	High School	Highlights difficulties faced by students in mastering fundamental chemistry concepts.

Enhanced Engagement and Conceptual Understanding

The findings in Table 1 highlight the transformative role of gamification, immersive virtual reality (VR), and molecular visualization tools in enhancing student engagement and understanding in chemistry education. Gamification, as explored by Othman (2024), provides an interactive and competitive learning environment, motivating students to participate actively. This approach transforms abstract concepts into relatable challenges, which is critical for engaging high school students who might otherwise struggle with the complexity of chemistry.

Similarly, Li (2024) demonstrated the potential of molecular visualization devices in higher education to clarify spatial and geometric complexities of molecular structures. These tools allow students to interact with three-dimensional models, enhancing their grasp of atomic arrangements and reactions. Aliev (2023) further underscores the effectiveness of VR in making chemistry more relevant and accessible. By immersing students in virtual laboratories, VR bridges the gap between theoretical learning and real-world applications, particularly in areas such as reaction mechanisms and spectroscopy.

These strategies align with constructivist theories, where learners build knowledge through active exploration and contextual experiences. When students visualize chemical phenomena in a tangible format, their ability to internalize and apply this knowledge improves significantly. This finding also resonates with Vygotsky's Zone of Proximal Development (ZPD), where digital tools act as scaffolds to support students' independent learning.

Practical Applications in Laboratory Settings

Hands on laboratory experiences, as highlighted by Gupta and Sharma (2017) and Harahap et al. (2022), remain critical for cementing theoretical knowledge. Inquiry-based approaches, such as guided investigations, not only engage students but also develop essential scientific competencies, including hypothesis formulation and data interpretation. Harahap et al. noted that students exposed to guided inquiry in analytical chemistry demonstrated superior problem-solving skills compared to those in traditional instructional settings.

These findings underscore the importance of inquiry driven practices in fostering deeper understanding. Laboratory activities designed around real-world scenarios allow students to contextualize abstract concepts, making learning more meaningful. This approach also nurtures critical thinking, an essential skill for addressing complex problems in both academic and professional settings.

Critical Thinking and Problem-Solving

The studies reviewed highlight the significant improvements in critical thinking and problem-solving skills resulting from constructivist and inquiry based learning (IBL) approaches. For instance, Syahgiah (2023) and Pratiwi et al. (2022) found that guided inquiry modules encouraged students to question, analyze, and synthesize information, leading to improved metacognitive skills and academic performance.

Critical thinking is further enhanced by collaborative problem-solving activities. Broman et al. (2022) demonstrated that context-based chemistry problems required students to apply their knowledge to real life challenges, fostering both analytical and creative thinking. Such practices reflect Dewey's philosophy of experiential learning, where students learn by doing and reflecting on their experiences.

Cognitive and Theoretical Relevance

The cognitive benefits of hands-on, inquiry-driven learning experiences are evident across various studies. Goldschmidt and Bogner (2015) reported that practical laboratory work, particularly in genetic engineering, significantly improved students' cognitive achievement.

Students were not only able to grasp complex topics but also demonstrated greater retention of knowledge.

These findings suggest that engaging students in inquiry-based experiments enhances their ability to connect theoretical principles with practical outcomes. This approach aligns with Piaget's constructivist theory, which posits that knowledge is constructed through active exploration and interaction with the environment.

Additionally, the integration of AI tools, as discussed by Daher et al. (2023), provides new avenues for enhancing problem-solving capabilities. By offering instant feedback and adaptive learning paths, AI technologies support personalized learning experiences, enabling students to navigate challenging topics with confidence.

Challenges and Barriers to Implementation

Despite the promising outcomes of constructivist and IBL strategies, significant challenges remain. Resource limitations and teacher preparedness were recurring themes in the reviewed studies. Mohammed and Amponsah (2021) noted that many educators lacked the training to effectively implement inquiry-based methods, often reverting to traditional lecture-based approaches.

Moreover, Wei et al. (2022) emphasized the role of institutional support in fostering a culture of inquiry-based learning. Without adequate resources, such as laboratory equipment or digital tools, the scalability of these innovative practices is limited. Addressing these barriers requires a systemic approach, including targeted professional development programs and increased funding for educational infrastructure.

Comparative Insights and Future Directions

The divergence between high school and higher education findings underscores the need for adaptable pedagogical strategies. While gamification and context-based problems are particularly effective for engaging younger students, immersive VR and AI driven problem solving tools show greater relevance in tertiary education settings.

Future research should explore the longitudinal impact of constructivist and IBL strategies, particularly their role in shaping lifelong learning habits and professional competencies. Additionally, interdisciplinary approaches, such as integrating chemistry with environmental science or healthcare, can further contextualize learning and enhance student motivation.

Scientific Explanation

The integration of constructivist and IBL activities facilitates deeper learning and application of knowledge. By encouraging students to actively participate in the learning process, these strategies foster a sense of ownership over their education. This approach aligns with Bandura's social cognitive theory, which emphasizes the role of self efficacy in learning.

Moreover, hands on experiences, such as laboratory investigations, develop critical thinking and analytical skills. Students learn to formulate hypotheses, test their ideas, and draw evidence-based conclusions, which are essential for scientific inquiry.

The findings from Table 1 and the reviewed literature illustrate the transformative potential of constructivist and inquiry-based learning strategies in chemistry education. By fostering engagement, critical thinking, and practical application, these approaches address the limitations of traditional rote learning methods. However, to realize their full potential, systemic changes in teacher training, resource allocation, and curriculum design are essential. These findings not only validate the efficacy of blended learning approaches but also provide a roadmap for their broader adoption in diverse educational contexts.

CONCLUSION

The integration of constructivist and inquiry-based learning (IBL) strategies in chemistry education represents a transformative pedagogical approach. This study highlights the substantial benefits of these methods, including enhanced student engagement, deeper conceptual understanding, and the development of critical thinking and problem-solving skills. By combining hands-on laboratory experiences with advanced tools such as virtual reality (VR), molecular visualization, and generative AI, students are empowered to bridge the gap between theoretical knowledge and practical applications. This research demonstrates that adopting these innovative approaches fosters a more inclusive and dynamic learning environment, preparing students for real-world challenges in STEM fields.

While the findings underscore the efficacy of these strategies, barriers such as resource limitations and insufficient teacher training remain significant. Addressing these challenges through systemic support, professional development, and investments in educational technology is crucial to fully realizing the potential of constructivist and IBL approaches.

RECOMMENDATIONS

Based on the findings of this study, it is recommended that, namely:

1. Teacher Training and Professional Development
   Institutions should prioritize equipping educators with the skills needed to implement constructivist and IBL strategies effectively. Workshops, certification programs, and collaborative learning communities can support this effort.
2. Infrastructure and Resource Investment
   Governments and educational stakeholders must allocate resources to enhance laboratory facilities, provide digital tools, and integrate technology like VR and AI into classrooms.
3. Curriculum Design
   A focus on interdisciplinary learning, linking chemistry with environmental science, healthcare, and technology, can increase student motivation and contextual understanding of the subject.
4. Future Research Directions
   Longitudinal studies are recommended to assess the sustained impact of constructivist and IBL strategies on student learning outcomes and career readiness. Additionally, exploring the integration of these methods across diverse educational contexts can yield broader insights.
5. Policy Advocacy
   Education policymakers should encourage the adoption of innovative teaching methods by aligning curriculum standards and assessments with constructivist and inquiry based pedagogies.

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BIBLIOGRAPHY

Adam, U. A., Onowugbeda, F. U., Islami, N., & Ogolo, K. G. (2024). Fostering engagement and learning outcomes: a comparative analysis of ethnochemical and stem-based pedagogies for chemistry learning in vocational high schools. J. Pendidik. Sains, 12(1), 1-6. https://doi.org/10.17977/jps.v12i12024p001

Aditomo, A. and Klieme, E. (2019). Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems.. https://doi.org/10.31235/osf.io/aqsbj

Ahmedi, V., Kurshumlija, A., & Ismajli, H. (2023). Teachers' attitudes towards constructivist approach to improving learning outcomes: The case of Kosovo. *International Journal of Instruction*, *16*(1), 441–454. https://doi.org/10.29333/iji.2023.16124a

Aidoo, B., Anthony-Krueger, C., Gyampoh, A., Tsyawo, N., & Quansah, F. (2022). A mixed-method approach to investigate the effect of flipped inquiry-based learning on chemistry students' learning. *European Journal of Science and Mathematics Education*, *10*(4), 507–518. https://doi.org/10.30935/scimath/12339

Akuma, F. and Callaghan, R. (2018). A systematic review characterizing and clarifying intrinsic teaching challenges linked to inquiry-based practical work. Journal of Research in Science Teaching, 56(5), 619-648. https://doi.org/10.1002/tea.21516

Aliev, R. (2023). Enhancing chemistry education's relevance and comprehension through immersive virtual reality. *Bio Web of Conferences*, *76*, 09006. https://doi.org/10.1051/bioconf/20237609006

Al-Zahrani, A. (2023). Empowering girls' higher education through social learning platforms. International Journal of Virtual and Personal Learning Environments, 13(1), 1-16. https://doi.org/10.4018/ijvple.331383

Anfa, Q. (2021). Training natural science education students as a pre-service teacher in constructing assessment instruments of cognitive domain through constructivist classroom. Jurnal Penelitian Pendidikan Ipa, 6(1), 1. https://doi.org/10.26740/jppipa.v6n1.p1-6

Aristeidou, M., Scanlon, E., & Sharples, M. (2020). Learning outcomes in online citizen science communities designed for inquiry. International Journal of Science Education Part B, 10(4), 277-294. https://doi.org/10.1080/21548455.2020.1836689

Aşıksoy, G. and Özdamlı, F. (2017). The flipped classroom approach based on the 5e learning cycle model - 5elfa/nastavni pristup obrnute učionice uutemeljen na 5e modelu ciklusa učenja. Croatian Journal of Education - Hrvatski Časopis Za Odgoj I Obrazovanje, 19(4). https://doi.org/10.15516/cje.v19i4.2564

Asmara, J. (2023). Online learning in supporting students' procedural abilities viewed from a constructivist approach.. https://doi.org/10.21203/rs.3.rs-3466684/v1

Astalini, A., Kurniawan, D., & Rini, E. (2022). Gender analysis in measurement materials: critical thinking ability and science processing skills. Jurnal Ilmiah Pendidikan Fisika Al-Biruni, 11(1), 113-128. https://doi.org/10.24042/jipfalbiruni.v11i1.11509

Aubrecht, K., Dori, Y., Holme, T., Lavi, R., Matlin, S., 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

Azer, S. and Azer, D. (2014). Group interaction in problem-based learning tutorials: a systematic review. European Journal of Dental Education, 19(4), 194-208. https://doi.org/10.1111/eje.12121

Bamidele, E., Adetunji, A., Awodele, B., & Irinoye, J. (2013). Attitudes of nigerian secondary school chemistry students towards concept mapping strategies in learning the mole concept. Academic Journal of Interdisciplinary Studies. https://doi.org/10.5901/ajis.2013.v2n2p475

Barak, M., Nissim, Y., & Ben-Zvi, D. (2011). Aptness between teaching roles and teaching strategies in ict-integrated science lessons. Interdisciplinary Journal of E-Skills and Lifelong Learning, 7, 305-322. https://doi.org/10.28945/1526

Bardakci, S., Dilara, K., Derya, A., & Alkan, M. (2021). How to become a constructivist teacher: the impact of philosophical thoughts on constructivist learning beliefs. Research in Pedagogy, 11(1), 214-233. https://doi.org/10.5937/istrped2101v214b

Barthlow, M. and Watson, S. (2014). The effectiveness of process-oriented guided inquiry learning to reduce alternative conceptions in secondary chemistry. School Science and Mathematics, 114(5), 246-255. https://doi.org/10.1111/ssm.12076

Bayram, A., Özsaban, A., Durgun, H., Aksoy, F., Turan, N., Dalcalı, B., … & Şahin, A. (2022). Nursing students' perceptions of nursing diagnoses, critical thinking motivations, and problem-solving skills during distance learning: a multicentral study. International Journal of Nursing Knowledge, 33(4), 304-311. https://doi.org/10.1111/2047-3095.12362

Beck, K., Witteck, T., & Eilks, I. (2010). Open experimentation on phenomena of chemical reactions via the learning company approach in early secondary chemistry education. Eurasia Journal of Mathematics Science and Technology Education, 6(3). https://doi.org/10.12973/ejmste/75237

Berry, M. (2023). Automated messaging delivered alongside behavioral treatment for weight loss: qualitative study. Jmir Formative Research, 7, e50872. https://doi.org/10.2196/50872

Bishop, R. (2023). The inclusion of adults with intellectual disabilities in health research – challenges, barriers and opportunities: a mixed-method study among stakeholders in england. Journal of Intellectual Disability Research, 68(2), 140-149. https://doi.org/10.1111/jir.13097

Bouwma-Gearhart, J., Adumat, S., Rogan-Klyve, A., & Bouwma, A. (2019). Modeling tropical diversity in the undergraduate classroom: novel curriculum to engage students in authentic scientific practices. The American Biology Teacher, 81(6), 417-422. https://doi.org/10.1525/abt.2019.81.6.417

Bramasta, I., Suartama, I., & Sudarma, I. (2022). Mesari (melajah aksara bali): interactive multimedia based on local wisdom for seventh grade in junior high school. Journal for Lesson and Learning Studies, 5(2), 172-180. https://doi.org/10.23887/jlls.v5i2.48979

Broman, K., Bernholt, S., & Christensson, C. (2020). Relevant or interesting according to upper secondary students? affective aspects of context-based chemistry problems. Research in

Science & Technological Education, 40(4), 478-498. https://doi.org/10.1080/02635143.2020.1824177

Burgh, G. and Nichols, K. (2012). The parallels between philosophical inquiry and scientific inquiry: implications for science education. Educational Philosophy and Theory, 44(10), 1045-1059. https://doi.org/10.1111/j.1469-5812.2011.00751.x

Cabalsa, J. and Abraham, L. (2020). Exploring biochemical reactions of proteins, carbohydrates, and lipids through a milk-based demonstration and an inquiry-based worksheet: a covid-19 laboratory experience. Journal of Chemical Education, 97(9), 2669-2677. https://doi.org/10.1021/acs.jchemed.0c00666

Cahyani, D., Yunita, F., & Ubaidillah, M. (2022). Application of inquiry collaborative constructivism model in biology learning respiratory system to improve students' critical thinking skills. Jurnal Pendidikan Sains (Jps), 10(1), 28. https://doi.org/10.26714/jps.10.1.2022.28-35

Cahyono, A., Asikin, M., Zahid, M., Laksmiwati, P., & Miftahudin, M. (2021). The roboste[m] project: using robotics learning in a stem education model to help prospective mathematics teachers promote students' 21st-centuryskills. International Journal of Learning Teaching and Educational Research, 20(7), 85-99. https://doi.org/10.26803/ijlter.20.7.5

Chang, B. (2019). Reflection in learning. Online Learning, 23(1). https://doi.org/10.24059/olj.v23i1.1447

Changwong, K., Sukkamart, A., & Sisan, B. (2018). Critical thinking skill development: analysis of a new learning management model for thai high schools. Journal of International Studies, 11(2), 37-48. https://doi.org/10.14254/2071-8330.2018/11-2/3

Chen, Q. (2023). The influence of constructivist learning style on college students' learning of basic subjects. Lecture Notes in Education Psychology and Public Media, 22(1), 327-334. https://doi.org/10.54254/2753-7048/22/20230334

Corr, C., Snodgrass, M., Love, H., Scott, I., Kim, J., & Andrews, L. (2020). Exploring the landscape of published mixed methods research in special education: a systematic review. Remedial and Special Education, 42(5), 317-328. https://doi.org/10.1177/0741932520924030

Cullipher, S., Sevian, H., & Talanquer, V. (2015). Reasoning about benefits, costs, and risks of chemical substances: Mapping different levels of sophistication. *Chemistry Education Research and Practice*, *16*(2), 377–392. https://doi.org/10.1039/c5rp00025d

Daher, W., Diab, H., & Rayan, A. (2023). Artificial intelligence generative tools and conceptual knowledge in problem-solving in chemistry. *Information*, *14*(7), 409. https://doi.org/10.3390/info14070409

Daudt, H., d'Archangelo, M., & Duquette, D. (2018). Spiritual care training in healthcare: does it really have an impact?. Palliative & Supportive Care, 17(2), 129-137. https://doi.org/10.1017/s1478951517001134

Deng, X. (2023). Applying hands-on inquiry learning in physical chemistry teaching practice to improve teaching quality. Indian Journal of Pharmaceutical Education and Research, 57(4), 1175-1182. https://doi.org/10.5530/ijper.57.4.140

Dewi, C., Inayah, S., Purba, L., & Awaliyah, N. (2023). Student perceptions of online-based chemistry learning implementation during the covid-19 pandemic. Jurnal Penelitian Pendidikan Ipa, 9(6), 4827-4835. https://doi.org/10.29303/jppipa.v9i6.4098

Diery, A., Vogel, F., Knogler, M., & Seidel, T. (2020). Evidence-based practice in higher education: teacher educators' attitudes, challenges, and uses. Frontiers in Education, 5. https://doi.org/10.3389/feduc.2020.00062

Duis, J. (2011). Organic chemistry educators’ perspectives on fundamental concepts and misconceptions: an exploratory study. Journal of Chemical Education, 88(3), 346-350. https://doi.org/10.1021/ed1007266

Duran, M. and Dökme, İ. (2016). The effect of the inquiry-based learning approach on student’s critical thinking skills. Eurasia Journal of Mathematics Science and Technology Education, 12(12). https://doi.org/10.12973/eurasia.2016.02311a

Dymond, S., Butler, A., Hopkins, S., & Patton, K. (2018). Curriculum and context: trends in interventions with transition-age students with severe disabilities. The Journal of Special Education, 52(3), 152-162. https://doi.org/10.1177/0022466918768776

Eilks, I., Gulacar, O., & Sandoval, J. (2018). Exploring the mysterious substances, X and Y: Challenging students’ thinking on acid–base chemistry and chemical equilibrium. *Journal of Chemical Education, 95*(4), 601–604. https://doi.org/10.1021/acs.jchemed.7b00404

Elisanti, E., Sajidan, S., & Prayitno, B. (2018). The effectiveness of inquiry lesson-based immunity system module to empower the students’ critical thinking skill. Edusains, 10(1). https://doi.org/10.15408/es.v10i1.7259

Eom, S. and Ashill, N. (2016). The determinants of students’ perceived learning outcomes and satisfaction in university online education: an update*. Decision Sciences Journal of Innovative Education, 14(2), 185-215. https://doi.org/10.1111/dsji.12097

Erdem, E., Özgür, S., Bayram, Z., Oskay, Ö., & Şen, Ş. (2014). Self-regulated learning in constructivist approach based science laboratory practices and opinions on constructivist approach. Problems of Education in the 21st Century, 59(1), 25-33. https://doi.org/10.33225/pec/14.59.25

Fajardo, M. and Bacarrisas, P. (2017). First-year college students’ knowledge in chemistry: is it adequate?. American Journal of Educational Research, 5(10), 1039-1043. https://doi.org/10.12691/education-5-10-5

Fang, G. and Teo, T. (2021). Investigating the associations of constructivist beliefs and classroom climate on teachers' self-efficacy among australian secondary mathematics teachers. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.626271

Faqih, A. (2023). Analysis of farmers' response to the rice farm insurance program (autp). Eduvest - Journal of Universal Studies, 3(8), 1405-1414. https://doi.org/10.59188/eduvest.v3i8.876

Ferreira, D., Sentanin, F., Parra, K., Bonini, V., Castro, M., & Kasseboehmer, A. (2021). Implementation of inquiry-based science in the classroom and its repercussion on the motivation to learn chemistry. Journal of Chemical Education, 99(2), 578-591. https://doi.org/10.1021/acs.jchemed.1c00287

Freeman, S., Eddy, S., McDonough, M., Smith, M., Okoroafor, N., Jordt, H., … & Wenderoth, M. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410-8415. https://doi.org/10.1073/pnas.1319030111

Furtak, E., Seidel, T., Iverson, H., & Briggs, D. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching. Review of Educational Research, 82(3), 300-329. https://doi.org/10.3102/0034654312457206

Goldschmidt, M. and Bogner, F. (2015). Learning about genetic engineering in an outreach laboratory: influence of motivation and gender on students' cognitive achievement. International Journal of Science Education Part B, 6(2), 166-187. https://doi.org/10.1080/21548455.2015.1031293

Goodwin, A., Smith, L., Souto-Manning, M., Cheruvu, R., Tan, M., Reed, R., … & Taveras, L. (2014). What should teacher educators know and be able to do? perspectives from practicing teacher educators. Journal of Teacher Education, 65(4), 284-302. https://doi.org/10.1177/0022487114535266

Gu, X., Song, X., Sun, H., Dong, M., Jing, L., Liu, G., … & Wu, J. (2016). Teaching reform of pharmaceutical chemistry with pbl method. Indian Journal of Pharmaceutical Education and Research, 50(4), 530-533. https://doi.org/10.5530/ijper.50.4.4

Gunawan, G., Suranti, N., Nisrina, N., & Herayanti, L. (2018). Students' problem-solving skill in physics teaching with virtual labs. Ijpte International Journal of Pedagogy and Teacher Education, 2, 10. https://doi.org/10.20961/ijpte.v2i0.24952

Gunnulfsen, A. (2021). Applying the integration dimensions of quantitative and qualitative methods in education policy research: lessons learned from investigating micro policymaking in norwegian schools. International Journal of Qualitative Methods, 20. https://doi.org/10.1177/16094069211028349

Guo, F., Young, J., Deese, N., Pickens-Flynn, T., Sellers, D., Perkins, D., … & Yakubu, M. (2021). Promoting the diversity, equity, and inclusion in organic chemistry education through undergraduate research experiences at wssu. Education Sciences, 11(8), 394. https://doi.org/10.3390/educsci11080394

Gupta, A. and Sharma, A. (2017). An assessment of the chemistry laboratory learning environments and teacher student interactions at the higher secondary level. International Journal of Research Studies in Education, 7(2). https://doi.org/10.5861/ijrse.2017.1713

Gupta, A., & Sharma, A. (2017). An assessment of the chemistry laboratory learning environments and teacher-student interactions at the higher secondary level. *International Journal of Research Studies in Education, 7*(2). https://doi.org/10.5861/ijrse.2017.1713

Harahap, F., Situmorang, M., & Nurfajriani, N. (2022). The development of guided inquiry-based learning resources as a strategy to achieve student competence in analytical chemistry.. https://doi.org/10.4108/eai.20-9-2022.2324794

Harta, J., Pamenang, F., Listyarini, R., Wijayanti, L., Hapsari, N., Ratri, M., & Lee, W. (2019). Analysis studentsâ€™ science process skills in senior high school practicum based on small scale chemistry (ssc). Unnes Science Education Journal, 8(3). https://doi.org/10.15294/usej.v8i3.31857

Hasan, R., Lukitasari, M., Utami, S., & Anizar, A. (2019). The activeness, critical, and creative thinking skills of students in the lesson study-based inquiry and cooperative learning. Jpbi (Jurnal Pendidikan Biologi Indonesia), 5(1), 77-84. https://doi.org/10.22219/jpbi.v5i1.7328

Hendratmoko, A. (2023). The impact of inquiry-based online learning with virtual laboratories on students' scientific argumentation skills. Turkish Online Journal of Distance Education, 24(4), 1-20. https://doi.org/10.17718/tojde.1129263

Hunt, P., McDonnell, J., & Crockett, M. (2012). Reconciling an ecological curricular framework focusing on quality of life outcomes with the development and instruction of standards-based academic goals. Research and Practice for Persons With Severe Disabilities, 37(3), 139-152. https://doi.org/10.2511/027494812804153471

Ibad, E. (2018). The effect of inquiry based chemistry laboratory on critical thinking. Journal of International Scientific Researches. https://doi.org/10.21733/ibad.423570

Islam, R., Haidoub, I., & Tarique, K. (2019). Enhancing quality of education: a case study on an international islamic school. Asian Academy of Management Journal, 24(Supp. 1), 141-156. https://doi.org/10.21315/aamj2019.24.s1.10

Jensen, M., Mattheis, A., & Johnson, B. (2012). Using student learning and development outcomes to evaluate a first-year undergraduate group video project. Cbe—life Sciences Education, 11(1), 68-80. https://doi.org/10.1187/cbe.11-06-0049

Jordan, C. (2013). Comparison of international baccalaureate (ib) chemistry students' preferred vs actual experience with a constructivist style of learning in a moodle e-learning environment. International Journal for Lesson and Learning Studies, 2(2), 155-167. https://doi.org/10.1108/20468251311323397

Juntunen, M. and Aksela, M. (2013). Life-cycle thinking in inquiry-based sustainability education – effects on students' attitudes towards chemistry and environmental literacy. Center for Educational Policy Studies Journal, 3(2), 157-180. https://doi.org/10.26529/cepsj.244

Kaatrakoski, H., Littlejohn, A., & Hood, N. (2016). Learning challenges in higher education: an analysis of contradictions within open educational practice. Higher Education, 74(4), 599-615. https://doi.org/10.1007/s10734-016-0067-z

Kanapathy, S., Lee, K., Mokhtar, M., Zakaria, S., Sivapalan, S., & Zahidi, A. (2019). Sustainable chemistry teaching at the pre-university level. International Journal of Sustainability in Higher Education, 20(4), 784-802. https://doi.org/10.1108/ijshe-10-2018-0186

Karpudewan, M., Ismail, Z., & Mohamed, N. (2011). Greening a chemistry teaching methods course at the school of educational studies, universiti sains malaysia. Journal of Education for Sustainable Development, 5(2), 197-214. https://doi.org/10.1177/097340821100500210

Karpudewan, M., Roth, W., & Sinniah, D. (2016). The role of green chemistry activities in fostering secondary school students' understanding of acid–base concepts and argumentation skills. Chemistry Education Research and Practice, 17(4), 893-901. https://doi.org/10.1039/c6rp00079g

Karyadi, P., Paristiowati, M., & Afrizal, A. (2020). Analysis the 21st century skills of students in chemical equilibrium learning with flipped classroom-collaborative problem solving model. JTK (Jurnal Tadris Kimiya), 5(1), 48-60. https://doi.org/10.15575/jtk.v5i1.7971

Kausar, A., Maryono, D., & Aristyagama, Y. (2021). Effective use of blended learning flipped classroom type reviewed from student learning outcomes in digital simulation subjects at smk negeri 3 surakarta. Journal of Informatics and Vocational Education, 3(3). https://doi.org/10.20961/joive.v3i3.47248

Kırkıç, K. and Arıkan, E. (2023). Primary school teachers' attitudes and views toward stem education. Science Education International, 34(2), 132-141. https://doi.org/10.33828/sei.v34.i2.7

Konst, T. and Scheinin, M. (2020). Why education 4.0 is not enough – education for sustainable future.. https://doi.org/10.21125/edulearn.2020.1661

Kucharczyk, S., Reutebuch, C., Carter, E., Hedges, S., Zein, F., Fan, H., & Gustafson, J. (2015). Addressing the needs of adolescents with autism spectrum disorder. Exceptional Children, 81(3), 329-349. https://doi.org/10.1177/0014402914563703

Kuter, S. and Özer, B. (2020). Student teachers' experiences of constructivism in a theoretical course built on inquiry-based learning. Journal of Qualitative Research in Education, 8(1), 135-155. https://doi.org/10.14689/issn.2148-2624.1.8c.1s.7m

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in thailand junior high schools. Heliyon, 7(6), e07309. https://doi.org/10.1016/j.heliyon.2021.e07309

Lazonder, A. and Harmsen, R. (2016). Meta-analysis of inquiry-based learning. Review of Educational Research, 86(3), 681-718. https://doi.org/10.3102/0034654315627366

Li, J. (2024). Molecular visualization device for education purposes: a novel approach for pedagogical enhancement in chemistry education.. https://doi.org/10.5121/csit.2024.140432

Li, Y., Zhang, X., Dai, D., & Hu, W. (2021). Curriculum innovation in times of the covid-19 pandemic: the thinking-based instruction theory and its application. Frontiers in Psychology, 12. https://doi.org/10.3389/fpsyg.2021.601607

Lieber, L. and Graulich, N. (2020). Thinking in alternatives—a task design for challenging students' problem-solving approaches in organic chemistry. Journal of Chemical Education, 97(10), 3731-3738. https://doi.org/10.1021/acs.jchemed.0c00248

Loshbaugh, H., Laursen, S., & Thiry, H. (2011). Reactions to changing times: trends and tensions in u.s. chemistry graduate education. Journal of Chemical Education, 88(6), 708-715. https://doi.org/10.1021/ed1008574

Mack, M. and Towns, M. (2016). Faculty beliefs about the purposes for teaching undergraduate physical chemistry courses. Chemistry Education Research and Practice, 17(1), 80-99. https://doi.org/10.1039/c5rp00148j

Maeng, J., Whitworth, B., Bell, R., & Sterling, D. (2020). The effect of professional development on elementary science teachers' understanding, confidence, and classroom implementation of reform-based science instruction. Science Education, 104(2), 326-353. https://doi.org/10.1002/sce.21562

Mahaffey, A. (2020). Mock urinalysis demonstration: Making connections among acid–base chemistry, redox reactions, and healthcare in an undergraduate nursing course. *Journal of Chemical Education*, *97*(7), 1976–1983. https://doi.org/10.1021/acs.jchemed.9b01086

Mahaffey, A. (2020). Mock urinalysis demonstration: making connections among acid–base chemistry, redox reactions, and healthcare in an undergraduate nursing course. Journal of Chemical Education, 97(7), 1976-1983. https://doi.org/10.1021/acs.jchemed.9b01086

Mahato, P., Angell, C., Teijlingen, E., & Simkhada, P. (2018). Using mixed-methods research in health & education in nepal. Journal of Health Promotion, 6, 45-48. https://doi.org/10.3126/jhp.v6i0.21803

Manan, A., Susanto, S., Yudianto, E. (2024). Developing the geometry teaching module by using a metacognitive approach in kurikulum merdeka to improve the students' critical thinking skills. International Journal of Current Science Research and Review, 07(05). https://doi.org/10.47191/ijcsrr/v7-i5-14

Mandler, D., Mamlok-Naaman, R., Blonder, R., Yayon, M., & Hofstein, A. (2012). High-school chemistry teaching through environmentally oriented curricula. Chemistry Education Research and Practice, 13(2), 80-92. https://doi.org/10.1039/c1rp90071d

Mangubat, F. (2023). Anecdotes of university students in learning chemistry: a philippine context. Jurnal Pendidikan Ipa Indonesia, 12(1), 24-31. https://doi.org/10.15294/jpii.v12i1.42120

Marshall, J., Smart, J., Lotter, C., & Sirbu, C. (2011). Comparative analysis of two inquiry observational protocols: striving to better understand the quality of teacher-facilitated inquiry-based instruction. School Science and Mathematics, 111(6), 306-315. https://doi.org/10.1111/j.1949-8594.2011.00091.x

McGaghie, W., Issenberg, S., Petrusa, E., & Scalese, R. (2010). A critical review of simulation-based medical education research: 2003â€ "2009. Medical Education, 44(1), 50-63. https://doi.org/10.1111/j.1365-2923.2009.03547.x

Mejias, S., Thompson, N., Sedas, R., Rosin, M., Soep, E., Peppler, K., & Bevan, B. (2021). The trouble with steam and why we use it anyway. Science Education, 105(2), 209-231. https://doi.org/10.1002/sce.21605

Michelene, T., Adams, J., Bogusch, E., Bruchok, C., Kang, S., Lancaster, M., & Yaghmourian, D. (2018). Translating the icap theory of cognitive engagement into practice. Cognitive Science, 42(6), 1777-1832. https://doi.org/10.1111/cogs.12626

Milner-Bolotin, M. (2012). Increasing interactivity and authenticity of chemistry instruction through data acquisition systems and other technologies. Journal of Chemical Education, 89(4), 477-481. https://doi.org/10.1021/ed1008443

Mitchell, E., Amer, Z., DiPillo, M., Mccall, M., & Wieser, S. (2021). University–church partnerships: a mechanism to enhance relationship health. Journal of Prevention & Intervention in the Community, 51(1), 7-22. https://doi.org/10.1080/10852352.2021.1924595

Mohammed, S. and Amponsah, K. (2021). Teachers' and educational administrators' conceptions of inquiry: do they promote or constrain inquiry-based science teaching in junior high schools?. Journal of Curriculum and Teaching, 10(3), 58. https://doi.org/10.5430/jct.v10n3p58

Moreno, R., Özoğul, G., & Reisslein, M. (2011). Teaching with concrete and abstract visual representations: effects on students' problem solving, problem representations, and learning perceptions.. Journal of Educational Psychology, 103(1), 32-47. https://doi.org/10.1037/a0021995

Morgan, K., Campbell, K., Sargeant, S., & Reidlinger, D. (2019). Preparing our future workforce: a qualitative exploration of dietetics practice educators' experiences. Journal of Human Nutrition and Dietetics, 32(2), 247-258. https://doi.org/10.1111/jhn.12620

Morgan, K., Reidlinger, D., Sargeant, S., Crane, L., & Campbell, K. (2018). Challenges in preparing the dietetics workforce of the future: an exploration of dietetics educators' experiences. Nutrition & Dietetics, 76(4), 382-391. https://doi.org/10.1111/1747-0080.12438

Mulyanti, S., Mardhiya, J., & Solihah, M. (2022). Perspectives on green chemistry and the application of nvivo 12 software: a case study of pandemic period in chemistry education. Scientiae Educatia, 11(1), 49. https://doi.org/10.24235/sc.educatia.v11i1.10280

Neally, K. (2022). An analysis of the underrepresentation of minoritized groups in science, technology, engineering, and mathematics education. School Science and Mathematics, 122(5), 271-280. https://doi.org/10.1111/ssm.12542

Ngah, R., Junid, J., & Osman, C. (2019). The links between role of educators, self-directed learning, constructivist learning environment and entrepreneurial endeavor: technology entrepreneurship pedagogical approach. International Journal of Learning Teaching and Educational Research, 18(11), 414-427. https://doi.org/10.26803/ijlter.18.11.25

Noguera, I., Albó, L., & Beardsley, M. (2022). University students' preference for flexible teaching models that foster constructivist learning practices. Australasian Journal of Educational Technology, 38(4), 22-39. https://doi.org/10.14742/ajet.7968

Ntim, S., Opoku-Manu, M., & Kwarteng, A. (2021). Post covid-19 and the potential of blended learning in higher institutions: exploring students and lecturers perspectives on learning outcomes in blended learning. European Journal of Education and Pedagogy, 2(6), 49-59. https://doi.org/10.24018/ejedu.2021.2.6.162

Nusantoro, E., Kurniawan, K., & Suharso, S. (2017). Graduate profile of guidance and counseling department faculty of education universitas negeri semarang. Couns-Edu| the International Journal of Counseling and Education, 2(2), 57-62. https://doi.org/10.23916/002017026820

Ocak, G. and Eğmir, E. (2016). The relationship between pre-service teachers' critical thinking tendencies and problem solving skills. Participatory Educational Research, spi16(2), 33-44. https://doi.org/10.17275/per.16.spi.2.4

Onwuegbuzie, A., Collins, K., Leech, N., & Jiao, Q. (2010). Mixed data collection and analysis for conducting research on giftedness and beyond.., 113-143. https://doi.org/10.1037/12079-006

Osman, K. and Sukor, N. (2013). Conceptual understanding in secondary school chemistry: a discussion of the difficulties experienced by students. American Journal of Applied Sciences, 10(5), 433-441. https://doi.org/10.3844/ajassp.2013.433.441

Othman, M. (2024). A journey into the thrilling depths of chemistry through gamification. *Quantum Journal of Social Sciences and Humanities*, *5*(2), 104–110. https://doi.org/10.55197/qjssh.v5i2.349

Pagliaro, M. (2019). Chemistry education fostering creativity in the digital era. Israel Journal of Chemistry, 59(6-7), 565-571. https://doi.org/10.1002/ijch.201800179

Pecore, J. (2012). Beyond beliefs: teachers adapting problem-based learning to preexisting systems of practice. Interdisciplinary Journal of Problem-Based Learning, 7(2). https://doi.org/10.7771/1541-5015.1359

Pedaste, M., Mäeots, M., Siiman, L., Jong, T., Riesen, S., Kamp, E., & Tsourlidaki, E. (2015). Phases of inquiry-based learning: definitions and the inquiry cycle. Educational Research Review, 14, 47-61. https://doi.org/10.1016/j.edurev.2015.02.003

Pence, H. and Losoff, B. (2011). Going beyond the textbook: the need to integrate open access primary literature into the chemistry curriculum. Chemistry Central Journal, 5(1). https://doi.org/10.1186/1752-153x-5-18

Pernaa, J. and Wiedmer, S. (2019). A systematic review of 3d printing in chemistry education – analysis of earlier research and educational use through technological pedagogical content knowledge framework. Chemistry Teacher International, 2(2). https://doi.org/10.1515/cti-2019-0005

Pramila-Savukoski, S., Juntunen, J., Tuomikoski, A., Kääriäinen, M., Tomietto, M., Kaučič, B., & Mikkonen, K. (2019). Mentors' self-assessed competence in mentoring nursing students in clinical practice: a systematic review of quantitative studies. Journal of Clinical Nursing, 29(5-6), 684-705. https://doi.org/10.1111/jocn.15127

Pratiwi, I., Ismanisa, I., & Nugraha, A. (2019). Development of guided inquiry-based modules to improve learning outcomes and metacognition skills of students. *Jurnal Pendidikan Kimia*, *11*(2), 49–56. https://doi.org/10.24114/jpkim.v11i2.14462

Pratiwi, I., Ismanisa, I., & Nugraha, A. (2019). Development of guided inquiry based modules to improve learning outcomes and metacognition skills of student. Jurnal Pendidikan Kimia, 11(2), 49-56. https://doi.org/10.24114/jpkim.v11i2.14462

Pratiwi, I., Ismanisa, I., & Nugraha, A. (2019). Development of guided inquiry based modules to improve learning outcomes and metacognition skills of student. Jurnal Pendidikan Kimia, 11(2), 49-56. https://doi.org/10.24114/jpkim.v11i2.14462

Prayitno, B., Widoretno, S., & Titikusumawati, E. (2022). Effectiveness of collaborative constructivist strategies to minimize gaps in students' understanding of biological concepts. International Journal of Emerging Technologies in Learning (Ijet), 17(11), 114-127. https://doi.org/10.3991/ijet.v17i11.29891

Purba, R. (2021). The effectiveness combination of blended learning and flipped classroom with edmodo as a digital media innovation for learning from home. Journal of Education Technology, 5(3). https://doi.org/10.23887/jet.v5i3.36210

Putri, A., Hadi, M., & Izzah, L. (2021). Analysis the influence of online learning on students' learning enthusiasm. Jetl (Journal of Education Teaching and Learning), 6(1), 90. https://doi.org/10.26737/jetl.v6i1.2312

Ralph, V., Scharlott, L., Schwarz, C., Becker, N., & Stowe, R. (2022). Beyond instructional practices: Characterizing learning environments that support students in explaining chemical phenomena. *Journal of Research in Science Teaching*, *59*(5), 841–875. https://doi.org/10.1002/tea.21746

Ralph, V., Scharlott, L., Schwarz, C., Becker, N., & Stowe, R. (2022). Beyond instructional practices: characterizing learning environments that support students in explaining chemical phenomena. Journal of Research in Science Teaching, 59(5), 841-875. https://doi.org/10.1002/tea.21746

Reib, M., Hoyles, C., Mujtaba, T., B, R., Rodd, M., Simon, S., & Stylianidou, F. (2011). Understanding participation rates in post-16 mathematics and physics: conceptualising and operationalising the upmap project. International Journal of Science and Mathematics Education, 9(2), 273-302. https://doi.org/10.1007/s10763-011-9286-z

Rendoth, T., Duncan, J., & Foggett, J. (2021). Inclusive curricula for students with severe intellectual disabilities or profound and multiple learning difficulties: a scoping review. Journal of Research in Special Educational Needs, 22(1), 76-88. https://doi.org/10.1111/1471-3802.12544

Rodriguez, J. (2024). Self-reported limitations in chemistry education research: providing specific and contextualized limitations supports researchers and practitioners. Journal of Chemical Education, 101(7), 2602-2607. https://doi.org/10.1021/acs.jchemed.4c00217

Ryu, M., Nardo, J., & Wu, 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

Şahin, U. (2013). The classroom teachers' skılls to organıze constructıvıst learnıng envıronment. International Journal of Elementary Education, 2(2), 16. https://doi.org/10.11648/j.ijeedu.20130202.11

Samosir, B. (2022). Implementation of process oriented guided inquiry learning model learning (pogil) on understanding of science concepts, skills science process and student's critical thinking ability. International Journal of Multidisciplinary Applied Business and Education Research, 3(9), 1673-1682. https://doi.org/10.11594/ijmaber.03.09.08

Sandlin, B., Harshman, J., & Yezierski, E. (2015). Formative assessment in high school chemistry teaching: investigating the alignment of teachers' goals with their items. Journal of Chemical Education, 92(10), 1619-1625. https://doi.org/10.1021/acs.jchemed.5b00163

Sari, M. and Muchlis, M. (2022). Improving critical thinking skills of high school students through guided inquiry implementation for learning reaction rate concept in chemistry. Jurnal Pijar Mipa, 17(2), 169-174. https://doi.org/10.29303/jpm.v17i2.3278

Schrader, D. (2015). Constructivism and learning in the age of social media: changing minds and learning communities. New Directions for Teaching and Learning, 2015(144), 23-35. https://doi.org/10.1002/tl.20160

Shamir-Inbal, T. and Blau, I. (2021). Active learning by visual programming: pedagogical perspectives of instructivist and constructivist code teachers and their implications on actual teaching strategies and students' programming artifacts. Journal of Educational Computing Research, 60(1), 28-55. https://doi.org/10.1177/07356331211017793

Shatayeva, A., Boranbayeva, A., Massaliyeva, Z., Batayev, D., & Makina, L. (2022). Technologies used in teaching children with special educational needs by future chemistry teacher. World Journal on Educational Technology Current Issues, 14(4), 1152-1162. https://doi.org/10.18844/wjet.v14i4.7672

She, H., Lin, H., & Huang, L. (2019). Reflections on and implications of the programme for international student assessment 2015 (pisa 2015) performance of students in taiwan: the role of epistemic beliefs about science in scientific literacy. Journal of Research in Science Teaching, 56(10), 1309-1340. https://doi.org/10.1002/tea.21553

Siddique, M. (2023). The role of resilience for developing the self-efficacy among chemistry students in pakistan. Vfast Transactions on Education and Social Sciences, 11(1), 38-48. https://doi.org/10.21015/vtess.v11i1.1401

Situmorang, M., Sinaga, M., Sitorus, M., & Sudrajat, A. (2022). Implementation of project-based learning innovation to develop students' critical thinking skills as a strategy to achieve analytical chemistry competencies. *Indian Journal of Pharmaceutical Education and Research, 56*(1s), s41–s51. https://doi.org/10.5530/ijper.56.1s.41

Soicher, R., Becker-Blease, K., & Bostwick, K. (2019). Adapting implementation science for higher education research: the systematic study of implementing evidence-based practices in college classrooms.. https://doi.org/10.31234/osf.io/f5kds

Sugano, S. and Nabua, E. (2020). Meta-analysis on the effects of teaching methods on academic performance in chemistry. International Journal of Instruction, 13(2), 881-894. https://doi.org/10.29333/iji.2020.13259a

Suningsih, T., Rukiyah, R., & Andarini, R. (2023). Development of digital teaching material in the south sumatra traditional games course. Jurnal Inovasi Teknologi Pendidikan, 10(1), 64-75. https://doi.org/10.21831/jitp.v10i1.54862

Suprabha, K. and Subramonian, G. (2021). Higher secondary commerce students' engagement and attitude towards blended learning environment. Journal of Psychological Research, 3(2), 1-6. https://doi.org/10.30564/jpr.v3i2.2965

Susilawati, D., Prayogo, T., & Santoso, A. (2022). Appreciative inquiry approach in limited face-to-face learning at sman 1 pusakanagara. Edunesia Jurnal Ilmiah Pendidikan, 3(2), 111-121. https://doi.org/10.51276/edu.v3i2.225

Sutarto, S., Indrawati, I., Prihatin,J., Dwi, P. A.*(2018). Geometrical* optics process image-based worksheets for enhancing students' higher-order thinking skills and self-regulated learning. Jurnal Pendidikan Ipa Indonesia, 7(4). https://doi.org/10.15294/jpii.v7i4.14563

Syahgiah, L. (2023). Effects of inquiry learning on students' science process skills and critical thinking: A meta-analysis. *Jurnal Pendidik IPA*, *1*(1), 16–28. https://doi.org/10.24036/jipt/vol1-iss1/9

Syahid, A. (2023). Meta-analysis of constructivist learning models in improving student learning outcomes. Tafkir Interdisciplinary Journal of Islamic Education, 4(4), 625-634. https://doi.org/10.31538/tijie.v4i4.718

Szozda, A. (2024). "systems thinking (st) encourages a safe space to offer different perspectives and insights": student perspectives and experiences with st activities. Journal of Chemical Education, 101(6), 2290-2307. https://doi.org/10.1021/acs.jchemed.4c00080

Szozda, A., Bruyere, K., Lee, H., Mahaffy, P., & Flynn, A. (2022). Investigating educators' perspectives toward systems thinking in chemistry education from international contexts. Journal of Chemical Education, 99(7), 2474-2483. https://doi.org/10.1021/acs.jchemed.2c00138

Szteinberg, G., Balicki, S., Banks, G., Clinchot, M., Cullipher, S., Huie, R., & Sevian, H. (2014). Collaborative professional development in chemistry education research: bridging the gap between research and practice. Journal of Chemical Education, 91(9), 1401-1408. https://doi.org/10.1021/ed5003042

Teig, N., Scherer, R., & Nilsen, T. (2018). More isn't always better: the curvilinear relationship between inquiry-based teaching and student achievement in science. Learning and Instruction, 56, 20-29. https://doi.org/10.1016/j.learninstruc.2018.02.006

Terrion, J. and Aceti, V. (2012). Perceptions of the effects of clicker technology on student learning and engagement: a study of freshmen chemistry students. Research in Learning Technology, 20(2), 16150. https://doi.org/10.3402/rlt.v20i0.16150

Tham, T., Burr, B., & Boohan, M. (2017). Evaluation of feedback given to trainees in medical specialties. Clinical Medicine, 17(4), 303-306. https://doi.org/10.7861/clinmedicine.17-4-303

Theobald, E., Hill, M., Tran, E., Agrawal, S., Arroyo, E., Behling, S., & Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences*, *117*(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

Thomas, A., Menon, A., Boruff, J., Rodríguez, A., & Ahmed, S. (2014). Applications of social constructivist learning theories in knowledge translation for healthcare professionals: A scoping review. *Implementation Science*, *9*(1). https://doi.org/10.1186/1748-5908-9-54

Ural, E. (2016). The effect of guided-inquiry laboratory experiments on science education students' chemistry laboratory attitudes, anxiety and achievement. Journal of Education and Training Studies, 4(4). https://doi.org/10.11114/jets.v4i4.1395

Utami, B., Saputro, S., Ashadi, A., Masykuri, M., & Sutanto, A. (2017). Implementation of problem solving with concept map to improve critical thinking skills and chemistry learning achievement.. https://doi.org/10.2991/ictte-17.2017.39

Vaismoradi, M., Turunen, H., & Bondas, T. (2013). Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. Nursing and Health Sciences, 15(3), 398-405. https://doi.org/10.1111/nhs.12048

Vintere, A. (2018). A constructivist approach to the teaching of mathematics to boost competences needed for sustainable development. Rural Sustainability Research, 39(334), 1-7. https://doi.org/10.2478/plua-2018-0001

Walker, P., Carson, K., Jarvis, J., McMillan, J., Noble, A., Armstrong, D., & Palmer, C. (2018). How do educators of students with disabilities in specialist settings understand and apply the australian curriculum framework?. Australasian Journal of Special and Inclusive Education, 42(02), 111-126. https://doi.org/10.1017/jsi.2018.13

Walters, L. (2015). Perceptions of the effects of a constructivist classroom approach on academic service-learning: an exploratory study. The BRC Academy Journal of Business, 5(1), 35-65. https://doi.org/10.15239/j.brcacadjb.2015.04.01.ja03

Wan, Y. and Bi, H. (2015). Representation and analysis of chemistry core ideas in science education standards between china and the united states. Journal of Chemical Education, 93(1), 70-78. https://doi.org/10.1021/ed500861g

Wardani, S., Nurhayati, Safitri, S., A. (2016). The effectiveness of the guided inquiry learning module towards students. International Journal of Science and Research (Ijsr), 5(6), 1589-1594. https://doi.org/10.21275/v5i6.nov164512

Watagodakumbura, C. (2015). Reviewing the purpose of education and challenges faced in implementing sound pedagogical practices in the presence of emerging evidence from neuroscience. World Journal of Education, 5(6). https://doi.org/10.5430/wje.v5n6p23

Wati, S., Idrus, A., & Syukur, A. (2021). Analysis of student scientific literacy: study on learning using ethnoscience integrated science teaching materials based on guided inquiry. Jurnal Pijar Mipa, 16(5), 624-630. https://doi.org/10.29303/jpm.v16i5.2292

Weil, L., Fleming, S., Dumontheil, I., Kilford, E., Weil, R., Rees, G., … & Blakemore, S. (2013). The development of metacognitive ability in adolescence. Consciousness and Cognition, 22(1), 264-271. https://doi.org/10.1016/j.concog.2013.01.004

Wells, T., Matthews, J., Caudle, L., Lunceford, C., Clement, B., & Anderson, R. (2015). The infusion of inquiry-based learning into school-based agricultural education: a review of literature. Journal of Agricultural Education, 56(4), 169-181. https://doi.org/10.5032/jae.2015.04170

Wiles, M. (2019). Designing a 21st century chiropractic educational program: a time for reflection, a time for action. Journal of Chiropractic Education, 34(2), 172-176. https://doi.org/10.7899/jce-18-31

Wilhelm, J. and Fisher, M. (2019). Creating academic teacher scholars in stem education by preparing preservice teachers as researchers., 281-296. https://doi.org/10.1007/978-3-030-11066-6_18

Windasari, W., Karwanto, K., Supriyanto, S., & Setiani, P. (2022). Factors affecting teacher digital competence : an exploratory factor analysis. Jurnal Kependidikan Jurnal Hasil Penelitian Dan Kajian Kepustakaan Di Bidang Pendidikan Pengajaran Dan Pembelajaran, 8(4), 1029. https://doi.org/10.33394/jk.v8i4.6095

Witri, R. (2023). Integrated green chemistry problem-based learning module development to improve science process skills senior high school students on basic chemicals law. Jurnal Penelitian Pendidikan Ipa, 9(8), 6188-6196. https://doi.org/10.29303/jppipa.v9i8.4380

Wright, L., Fisk, J., & Newman, D. (2014). Dna → rna: what do students think the arrow means?. Cbe life Sciences Education, 13(2), 338-348. https://doi.org/10.1187/cbe.cbe-13-09-0188

Wu, M. and Yezierski, E. (2023). Secondary chemistry teacher learning: precursors for and mechanisms of pedagogical conceptual change. Chemistry Education Research and Practice, 24(1), 245-262. https://doi.org/10.1039/d2rp00160h

Yakar, U., Sulu, A., & Calis, N. (2020). From constructivist educational technology to mobile constructivism: how mobile learning serves constructivism?. International Journal of Academic Research in Education, 6(1), 56-75. https://doi.org/10.17985/ijare.818487

Yong, L., Xin, X., Wee, J., Poopalalingam, R., Kwek, K., & Thumboo, J. (2020). Perception survey of crisis and emergency risk communication in an acute hospital in the management of covid-19 pandemic in singapore. BMC Public Health, 20(1). https://doi.org/10.1186/s12889-020-10047-2

Yuksel, M. (2012). Evaluating the effectiveness of the chemistry education by using the analytic hierarchy process. International Education Studies, 5(5). https://doi.org/10.5539/ies.v5n5p79

Yulkifli, Y., Jaafar, R., & Resnita, L. (2020). Developing student worksheets using inquiry-based learning model with scientific approach to improve tenth grade students' physics competence. Jurnal Penelitian Fisika Dan Aplikasinya (Jpfa), 10(1), 56. https://doi.org/10.26740/jpfa.v10n1.p56-70

Zhang, X. (2019). An empirical approach and implications for teachers to begin constructivist teaching. Open Journal of Social Sciences, 07(10), 375-386. https://doi.org/10.4236/jss.2019.710032

Zoller, U. (2012). Science education for global sustainability: What is necessary for teaching, learning, and assessment strategies? *Journal of Chemical Education, 89*(3), 297–300. https://doi.org/10.1021/ed300047v

ssИванова, E., Klarin, M., & Osmolovskaya, I. (2021). Topical directions of didactics development in the xxi century. SHS Web of Conferences, 101, 03016. https://doi.org/10.1051/shsconf/202110103016