Reconceptualising Problem-Based Learning: A Framework for 21st-Century Skills and Character Development

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Abstract **–This article examines Problem-Based Learning (PBL) as a holistic framework for fostering 21st-century skills and character education within science learning, supported by the integration of multiple learning theories. Drawing from a qualitative case study conducted in the Water Vision Program (WVP)—a school-based environmental initiative implemented through PBL—the study applies Constructivist, Sociocultural, Cognitive, and Social Constructivist theories together with Lickona's Character Education Theory to interpret how PBL supports learner development. These theoretical foundations help explain how students construct knowledge, collaborate, regulate their thinking, and engage ethically with real-world environmental challenges. Data were collected through semi-structured interviews, a focus group discussion, and document analysis to capture students' experiences across authentic PBL tasks such as community outreach, awareness campaigns, and project-based investigations. Findings reveal that the WVP facilitated substantial growth across cognitive, interpersonal, and intrapersonal domains. Students demonstrated strengthened scientific reasoning, problem-solving, and the ability to apply scientific knowledge meaningfully. Interpersonal gains included improved communication, teamwork, negotiation, and leadership as students coordinated activities with peers and community members. intrapersonal, the program fostered perseverance, empathy, responsibility, confidence, and environmental awareness, reflecting key elements of character education. Based on these empirical insights, the article presents an integrated PBL framework illustrating how theoretical principles converge in practice to promote holistic learner development. The synthesis underscores PBL's potential to unite cognitive skill-building with moral and personal growth, positioning science learning as both intellectually engaging and ethically grounded. Implications are discussed for strengthening values-driven and inquiry-based science education through curriculum design, teacher professional development, and future research in Malaysian and broader educational contexts.**

Keywords **– Problem-Based Learning (PBL), Constructivist Theory, Sociocultural Theory, Cognitive Learning Theory, Character Education, 21st-Century Skills, Science Education**

I. INTRODUCTION

Global educational reforms have increasingly emphasised the need to prepare learners for a world characterised by complexity, uncertainty, and rapid technological change.

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The 21st century demands not only academic proficiency but also holistic competencies that enable learners to think critically, act ethically, and collaborate effectively in addressing real-world challenges (UNESCO, 2015). In response, educational systems worldwide have shifted from teacher-centred instruction toward learner-centred, inquiry-based pedagogies that prioritise critical thinking, problem-solving, creativity, and character formation (OECD, 2018).

In Malaysia, these global aspirations are mirrored in the Malaysia Education Blueprint 2013–2025, which calls for developing students who are intellectually competent, ethically grounded, and socially responsible (Ministry of Education Malaysia, 2013). The KSSM Science Curriculum Framework reinforces this goal by promoting inquiry, higher-order thinking, and real-world application. Despite these aspirations, classroom practices in many Malaysian schools remain largely examination-oriented and teacher-dominated (Teo, 2019). This disconnect between policy intent and pedagogical reality underscores the need for teaching frameworks that unify skill development, character education, and contextualised learning.

Problem-Based Learning (PBL) offers such potential. Originally developed in medical education (Barrows & Tamblyn, 1980), PBL has since evolved into a widely adopted student-centred approach across disciplines. PBL engages learners in solving authentic, ill-structured problems that mirror real-world complexity, thereby fostering cognitive, interpersonal, and intrapersonal growth. However, while PBL's cognitive benefits are well documented, its moral and character-building dimensions remain underexplored in secondary education, particularly within Malaysian science classrooms.

This paper reconceptualises PBL as an integrative framework for developing 21st-century competencies and character within science education. It synthesises insights from key learning theories—Constructivist, Sociocultural, Cognitive, and Social Constructivist—alongside Lickona's Character Education Theory to articulate how PBL bridges knowledge construction with ethical engagement. Through this synthesis, the paper proposes a conceptual model situating PBL as a transformative pedagogy capable of realising Malaysia's educational reform agendas and global sustainable development goals.

II. METHODOLOGY

This qualitative case study was framed within an interpretive paradigm, guided by relativist ontology and constructivist epistemology, which view reality as socially constructed and shaped by participants' meanings and interactions (Crotty, 1998; Creswell, 2013; Creswell &

Poth, 2018). The study focused on students and teacher facilitators involved in the Water Vision Program (WVP), selected through purposeful sampling due to their direct engagement with the programme. Data were gathered through semi-structured interviews conducted via Google Meet, along with a face-to-face focus group discussion. All interviews were audio-recorded with informed consent and transcribed verbatim. Document analysis further enriched the dataset, incorporating student testimonials, programme posters, PowerPoint slides, photographs, reports, and video artefacts related to the WVP, consistent with qualitative approaches emphasising multiple sources of evidence (Merriam, 2009; Yin, 2011, 2018).

Data analysis followed Braun and Clarke's (2006) six-phase thematic analysis, supported by NVivo for organising transcripts, coding, memo writing, and generating theme structures. The analytic process was iterative and inductive, allowing themes to emerge from repeated engagement with the data. Constant comparison was used across interviews, focus group accounts, and documents to refine categories and ensure coherent theme development. Throughout analysis, documentation of insights and decisions aligned with qualitative traditions that highlight the recursive movement between data and interpretation (Miles, Huberman, & Saldaña, 2014; Richards, 2015; Stake, 1995).

Trustworthiness was enhanced through triangulation of data sources and methods, reflexive engagement with the dataset, and maintaining a clear audit trail that captured coding decisions, memo progressions, and theme refinement (Lincoln & Guba, 1985; Denzin, 1978). Ethical procedures included securing informed consent, ensuring confidentiality, and conducting the study in accordance with institutional guidelines. These methodological procedures provided a robust foundation for examining how students experienced cognitive, interpersonal, and intrapersonal development through their involvement in the PBL-driven Water Vision Program.

III. THEORETICAL AND CONCEPTUAL FOUNDATIONS

Constructivist Learning Theory

Constructivism posits that learners actively construct knowledge by integrating new experiences with prior understanding (Piaget, 1972; Matthews, 2002). Learning is an active, self-regulated process involving exploration, questioning, and reflection. Within this view, the teacher's role shifts from transmitter of knowledge to facilitator of meaning-making. Constructivist classrooms emphasise authentic, contextualised learning experiences that mirror real-life problems, encouraging students to test hypotheses, engage in dialogue, and refine understanding through feedback (Akcay, 2009).

In the context of PBL, constructivism underpins the process of knowledge construction through inquiry. Students engage with authentic problems that lack predetermined solutions, requiring them to draw upon existing knowledge while generating new insights collaboratively. The iterative cycle of hypothesis formation, experimentation, and reflection reflects the constructivist emphasis on active learning. Through this process, learners internalise knowledge deeply rather than memorising content superficially.

Vygotsky's Sociocultural Theory

Vygotsky extends constructivism by emphasising the social mediation of learning. Knowledge is co-constructed through interaction with more knowledgeable others within a cultural and linguistic context (Vygotsky, 1978). Two key concepts—the Zone of Proximal Development (ZPD) and scaffolding—illustrate how guidance supports learners' progression from dependence to autonomy.

In PBL environments, scaffolding occurs as teachers and peers guide inquiry processes, helping learners articulate questions, synthesise data, and evaluate solutions. As competence increases, scaffolds are gradually removed, fostering independence. Cultural tools such as language, digital media, and symbols further mediate cognitive activity, allowing learners to externalise thinking and construct shared understanding (Daneshfar & Moharami, 2018). This social dimension of PBL fosters not only cognitive but also interpersonal growth—communication, empathy, and teamwork—key components of 21st-century skills.

Cognitive Learning Theory

Cognitive Learning Theory examines how information is perceived, processed, and stored. It highlights the importance of attention, memory, and reasoning in transforming sensory input into meaningful knowledge (Çeliköz et al., 2019). Piaget's developmental framework identifies the formal operational stage—typical of adolescents—as the phase where abstract reasoning, hypothesis testing, and metacognition mature (Pakpahan & Saragih, 2022).

In science-based PBL, learners engage cognitive processes such as information gathering, analysis, and evaluation when investigating environmental or scientific issues. The structure of PBL—problem analysis, inquiry, synthesis, and reflection—supports executive cognition and metacognitive regulation, enabling students to monitor their learning progress. This theoretical lens clarifies how PBL nurtures complex cognitive operations essential for scientific literacy and problem-solving.

Social Constructivist Theory

Social Constructivist Theory integrates cognitive and sociocultural perspectives by emphasising collaboration and dialogue as vehicles for meaning-making (Palincsar, 1998). Learning is viewed as a social negotiation where multiple perspectives converge to form shared understanding. In PBL, group discussions, argumentation, and collective reflection embody this principle. Learners construct shared knowledge while developing communication, leadership, and conflict-resolution skills—attributes critical for collaborative inquiry and teamwork.

Social constructivism also recognises the affective dimension of learning: respectful dialogue, trust, and empathy create a safe space for intellectual risk-taking. Thus, PBL not only facilitates cognitive development but also nurtures interpersonal and emotional intelligence, positioning learning as a holistic social process.

Lickona Character Education

Lickona & Davidson (2005) defines character as the integration of moral knowing, moral feeling, and moral action. Moral knowing involves understanding ethical principles; moral feeling refers to empathy and conscience; moral action translates values into behaviours. Effective character education, therefore, engages cognition, emotion, and behaviour within authentic contexts.

PBL embodies this integration by immersing learners in real-world challenges that demand ethical decision-making and social responsibility. Students experience moral dilemmas—balancing environmental, social, and practical considerations—while exercising empathy and perseverance. Teachers serve as moral models, scaffolding reflection and guiding students toward responsible choices. This alignment illustrates how PBL operationalises character education through lived experience rather than moral instruction.

IV. REVIEW OF PAST RESEARCH ON PROBLEM-BASED LEARNING

Global Trends and Evidence

Problem-Based Learning (PBL) has evolved over the past five decades from its origins in medical education (Barrows & Tamblyn, 1980) into a transformative pedagogical model used across diverse disciplines and educational levels. Global research consistently affirms its effectiveness in developing higher-order thinking, collaboration, and motivation through authentic, inquiry-driven experiences (Hmelo-Silver, 2004; Loyens et al., 2008). Studies highlight that PBL fosters deep learning by positioning students as active constructors of knowledge who identify, analyse, and propose solutions to complex problems rather than passively receiving information (Nguyen et al., 2024).

In science education, PBL has been shown to enhance conceptual understanding and promote scientific reasoning. Bosica et al. (2021) found that integrating PBL in physics and biology improved students' ability to connect theoretical principles with real-world applications. Similarly, Pu et al. (2019) observed that science students who engaged in problem-based inquiry demonstrated greater retention of concepts and improved attitudes toward collaborative learning. Across these studies, a consistent pattern emerges: authentic problem contexts and peer collaboration foster curiosity, persistence, and intrinsic motivation, reinforcing the constructivist notion that learning occurs most effectively through active engagement.

Cognitive and Metacognitive Outcomes

Empirical research also reveals that PBL nurtures essential cognitive and metacognitive processes. Studies by Seibert (2021) and Bao and Koenig (2019) demonstrate that PBL enhances students' ability to reason critically, evaluate evidence, and transfer knowledge to novel situations. Learners develop stronger executive functioning skills—including planning, cognitive flexibility, and self-regulation—through iterative problem analysis and reflection cycles. Recent work further extends this cognitive perspective. For example, Bulut Ates and Aktamis (2024) found that integrating PBL with structured cognitive tools such as the Cognitive Research Trust (CoRT) techniques significantly improved students' scientific creativity, highlighting PBL's role in fostering divergent thinking and more flexible cognitive processing. These findings align with Cognitive Learning Theory, which views learning as the internal processing and restructuring of knowledge (Çeliköz et al., 2019). By requiring learners to evaluate information, test hypotheses, and monitor their thinking, PBL becomes a vehicle for metacognitive growth and self-directed learning (Pyle & Hung, 2019).

Social and Collaborative Dimensions

Beyond cognition, PBL's social dimensions have been widely documented. Collaborative inquiry encourages learners to exchange perspectives, negotiate understanding, and co-construct knowledge—processes closely linked to students' collaborative dispositions in group problem-solving (Aslan, 2021; Li et al., 2023). Crespo and Harper (2020) emphasised that group-based problem-solving activities also foster interpersonal communication, empathy, and respect for diversity—outcomes aligned with the principles of Social Constructivist and Sociocultural theories. Through interaction within the Zone of Proximal Development (ZPD), learners deepen conceptual understanding while simultaneously developing essential 21st-century interpersonal competencies such as teamwork, shared responsibility, and leadership (Chen & Kuo, 2019; Lim & Han, 2020).

Research further indicates that the collaborative inquiry central to PBL activates key elements of social cognition, particularly perspective-taking—the cognitive process through which individuals recognise, interpret, and respond to others' thoughts, emotions, and intentions. Taylor and Edwards (2021) argue that perspective-taking operates as a complex form of problem solving, requiring learners to evaluate differing viewpoints, anticipate others' needs, and coordinate shared meaning. Within PBL environments, these processes are continually exercised as students negotiate roles, justify decisions, and respond to peer input during group investigations. In this way, PBL indirectly contributes to character formation by fostering empathy, cooperation, and shared responsibility within learning communities.

Emerging Research on Character and Values in PBL

While most empirical studies emphasise cognitive and collaborative outcomes, an emerging body of research recognises PBL's potential in cultivating moral and character development. Lickona & Davidson (2025) argues that authentic learning environments and real-world responsibilities create powerful contexts for nurturing moral knowing, moral feeling, and moral action. These principles align closely with PBL, where students work through complex real-world issues—such as environmental sustainability or community welfare—that compel them to consider the moral and social implications of their actions. Recent studies support this perspective. Wibowo (2023) and Lonergan et al. (2022) show that PBL projects oriented toward social or environmental themes promote empathy, resilience, and civic engagement. Similarly, Routhe et al. (2025) demonstrate that ethical dimensions are inherently embedded within PBL, as learners must analyse stakeholder perspectives, negotiate value-laden decisions, and justify the consequences of their proposed solutions. Together, these insights highlight PBL's capacity to integrate cognitive learning with the development of ethical sensitivity, social responsibility, and character attributes essential for responsible citizenship.

Nevertheless, these moral dimensions remain underexplored in the PBL literature, particularly within secondary science education. Existing studies rarely address how PBL might systematically integrate character education principles into learning design. This conceptual paper addresses that gap by explicitly linking PBL with Lickona's Character Education Theory, positioning character development not as an incidental by-product but as an intentional educational outcome.

The Malaysian Context

In Malaysia, research on PBL has primarily focused on higher education, with comparatively fewer studies at the secondary level. Teo (2019) and Fadjarajani et al. (2024) highlight that while universities increasingly adopt PBL to enhance problem-solving and innovation, its implementation in schools remains limited due to curriculum constraints, examination pressures, and teacher readiness. Studies by Amira et al. (2019) and Kwan (2019) show that when effectively implemented, PBL in Malaysian science classrooms can improve students' engagement and scientific reasoning, yet challenges persist in sustaining collaborative learning and reflective assessment.

The Malaysia Education Blueprint (2013–2025) and the KSSM Science Curriculum explicitly promote inquiry, critical thinking, and ethical citizenship. However, the gap between policy and practice suggests that Malaysian classrooms need pedagogical frameworks that unite academic, social, and moral learning goals. The Water Vision Program (WVP), for example, demonstrates how authentic environmental issues can contextualise science learning while nurturing responsibility and community awareness. Such initiatives underscore the feasibility of PBL as a means to operationalise national educational aspirations within real-world contexts.

Conceptual Gap and Rationale

Synthesising these findings reveals a notable gap: although research confirms PBL's capacity to enhance cognitive and interpersonal skills, its role in systematically developing character and moral reasoning remains conceptually underdefined. Moreover, few studies have theorised how learning theories collectively explain the mechanisms by which PBL cultivates both intellectual and ethical growth. This gap provides the rationale for the present conceptual paper, which integrates Constructivist, Sociocultural, Cognitive, Social Constructivist, and Character Education theories into a unified model. The proposed framework reconceptualises PBL as a holistic pedagogy—one that simultaneously advances knowledge, skills, and values in alignment with Malaysia's education reform agenda and global 21st-century learning goals.

V. PROBLEM-BASED LEARNING AND THE 21ST - CENTURY EDUCATION AGENDA

Bridging Policy and Pedagogy

Malaysia's Education Blueprint (2013–2025) envisions learners who are "knowledgeable, thinking, bilingual, ethical, and patriotic." Similarly, the KSSM Science Curriculum promotes inquiry-based, student-centred learning aligned with global frameworks such as P21 and OECD Learning Framework 2030. These frameworks converge on three developmental domains—cognitive, interpersonal, and intrapersonal—representing holistic learner growth (Haug & Mork, 2021).

However, despite these frameworks, implementation gaps persist. Classrooms often prioritise rote knowledge over inquiry, limiting opportunities for creativity and moral reasoning. PBL offers a bridge between policy and practice by providing a structured yet flexible model that integrates higher-order thinking with ethical engagement. It transforms learning into a process of discovery, reflection, and contribution to real-world issues, aligning national reform with practical pedagogy.

Integrating Skill and Value Formation

PBL develops 21st-century competencies through authentic engagement.

- Cognitive Domain: Learners construct and apply knowledge to solve complex problems, promoting analytical reasoning and metacognitive awareness.
- Interpersonal Domain: Collaboration, negotiation, and communication foster teamwork and empathy.
- Intrapersonal Domain: Reflection, perseverance, and self-regulation strengthen motivation and moral character.

By connecting these domains, PBL transcends the traditional dichotomy between academic achievement and moral education. It fosters both intellectual rigour and ethical sensibility, positioning education as a process of holistic human development. A Conceptual Model for Integrative PBL

VI. A CONCEPTUAL MODEL FOR INTEGRATIVE PBL

Drawing from the four learning theories and Lickona's Character Education Theory, a conceptual synthesis can be proposed (Figure 1), the model integrates the following dimensions:

1. Constructivist Foundation: Learners build meaning through exploration and reflection.
2. Sociocultural Mediation: Social interaction, scaffolding, and cultural tools facilitate development within the ZPD.
3. Cognitive Processing: Attention, reasoning, and metacognition regulate learning.
4. Social Constructivism: Collaboration and dialogue lead to shared understanding.
5. Character Education: Ethical reasoning, empathy, and responsible action translate knowledge into moral practice.

Together, these processes form a dynamic learning ecology where students engage intellectually, socially, and ethically. PBL becomes a catalyst for *transformative learning*—a process through which students reframe perspectives and internalise values through active participation in real-world challenges.

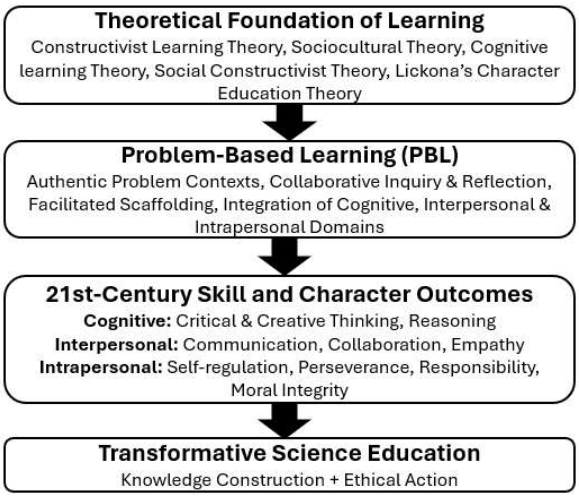

Figure 1. Integrative Problem-Based Learning (PBL) Model

Figure 1. Conceptual model illustrating how Problem-Based Learning (PBL) integrates multiple learning theories and character education to develop cognitive, interpersonal, and intrapersonal competencies for transformative science education. *(Source: Author's own synthesis based on Constructivist, Sociocultural, Cognitive, Social Constructivist, and Lickona's Character Education Theories.)*

VII. DISCUSSION: TOWARD TRANSFORMATIVE SCIENCE EDUCATION

PBL's integration of theory and practice positions it as a transformative framework for science education. It addresses three critical educational imperatives:

1. Bridging Knowledge and Application: PBL contextualises abstract scientific concepts within tangible societal issues such as environmental sustainability, fostering meaningful learning and scientific literacy.
2. Fostering Autonomy and Collaboration: Through scaffolded group inquiry, learners experience agency and accountability, developing both independence and teamwork.
3. Cultivating Character and Citizenship: Engaging with authentic environmental problems nurtures empathy, civic responsibility, and moral reasoning—qualities essential for responsible citizenship and sustainable development.

By merging cognitive, interpersonal, and intrapersonal growth, PBL transforms the science classroom into a microcosm of society—a place where students practice problem-solving, ethical reasoning, and cooperative action.

VIII. EMPIRICAL FINDINGS FROM THE DOCTORAL STUDY

The conceptual synthesis developed in this article is grounded in empirical insights extracted from the author's doctoral research on the Water Vision Program (WVP), a school-based environmental initiative implemented through a Problem-Based Learning (PBL) framework. The findings relevant to the theoretical argument advanced in this paper are integrated to demonstrate how the empirical patterns underpin the proposed conceptual model.

The analysis of student experiences revealed that the WVP's real-world environmental tasks—such as community outreach, awareness campaigns, data collection, and project planning—created meaningful opportunities for cognitive development. Students demonstrated growth in scientific understanding, problem-solving, reasoning, and the ability to connect classroom knowledge with actual environmental issues affecting their communities. The authenticity of the tasks strengthened their capacity to analyse problems, interpret scientific information, and apply what they learned in a purposeful context.

Interpersonal development emerged strongly across the dataset. Collaborative activities required students to negotiate roles, manage team responsibilities, communicate across different settings, and coordinate outreach activities with diverse audiences. Participation in school-level and community-level events enhanced their confidence in public speaking, teamwork, and leadership. Students learned to navigate group dynamics, resolve conflicts, and adjust to the demands of working with peers under real-world constraints, contributing to stronger communication and social interaction skills.

Intrapersonal growth was also evident. Students reported increased self-confidence, resilience, and initiative as they faced challenges such as time pressures, unfamiliar tasks, public engagements, and technical requirements associated with environmental projects. The iterative nature of planning, implementing, and refining their activities fostered self-management, perseverance, and a deeper sense of responsibility toward environmental stewardship. These experiences encouraged students to reflect on their personal growth and recognise how their actions contributed to wider community impact.

Collectively, these empirical patterns indicate that the WVP, implemented through PBL principles, supported holistic student development in cognitive, interpersonal, and intrapersonal domains. These insights provide empirical grounding for the conceptual synthesis proposed in this article, reinforcing the argument that PBL-driven environmental programs can serve as powerful platforms for cultivating 21st-century learner characteristics.

IX. IMPLICATIONS

Theoretical Implications

This synthesis demonstrates that PBL operationalises multiple learning theories simultaneously. It validates constructivist principles of active learning, extends Vygotskian scaffolding through social mediation, reinforces cognitive processes of reasoning and reflection, and manifests social constructivist co-learning. When integrated with character education, PBL becomes a holistic paradigm that unites knowledge, skills, and values—an essential reorientation for 21st-century education.

Practical Implications

1. Curriculum Design: Embedding PBL in science curricula can align classroom practices with policy goals of inquiry, innovation, and ethical awareness.
2. Teacher Professional Development: Educators require training to shift from directive instruction to facilitative mentoring that nurtures autonomy and reflection.
3. Assessment Reform: Evaluations should include reflective journals, portfolios, and collaborative outputs to capture both cognitive and character outcomes.
4. Community Engagement: Linking classroom projects to local environmental initiatives deepens relevance and sustains motivation.

X. CONCLUSION

Problem-Based Learning offers a powerful integrative framework for nurturing the full spectrum of 21st-century competencies—cognitive agility, collaborative skill, and moral integrity. Synthesising multiple learning theories and Lickona's Character Education model, this conceptual paper positions PBL as both an epistemological and ethical pedagogy. It responds to Malaysia's educational transformation agenda by bridging policy ideals with actionable classroom practice.

Future research should empirically validate this framework through longitudinal and cross-contextual studies, examining how PBL fosters enduring character development and learner agency across disciplines. In doing so, education can move beyond knowledge transmission toward the cultivation of thoughtful, ethical, and resilient learners prepared to contribute meaningfully to an interconnected world.

REFERENCES

Akçay, B. (2009). Problem-based learning in science education. *Turkish Online Journal of Science Education*, 6(1), 26–36.

Amira, T., Lamia, M., & Hafidi, M. (2019). Learning styles in a collaborative algorithmic problem-based learning. *The Review of Socionetwork Strategies*, 13, 3–17.

Aslan, A. (2021). Problem-based learning in live online classes: Learning achievement, problem-solving skill, communication skill, and interaction. *Computers & Education*, 171, Article 104237. https://doi.org/10.1016/j.compedu.2021.104237

Bao, L., & Koenig, K. (2019). Physics education research for 21st-century learning. *Disciplinary and Interdisciplinary Science Education Research*, 1, Article 2. https://doi.org/10.1186/s43031-019-0007-8

Barrows, H. S., & Tamblyn, R. M. (1980). *Problem-based learning: An approach to medical education*. Springer.

Bosica, J., Pyper, J. S., & MacGregor, S. (2021). Incorporating problem-based learning in a secondary school mathematics preservice teacher education course. *Teaching and Teacher Education*, 102, Article 103335. https://doi.org/10.1016/j.tate.2021.103335

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Bulut Ates, C., & Aktamis, H. (2024). Investigating the effects of creative educational modules blended with Cognitive Research Trust (CoRT) techniques and problem-based learning (PBL) on students' scientific creativity skills and perceptions in science education. *Thinking Skills and Creativity, 51*, 101471. https://doi.org/10.1016/j.tsc.2024.101471

Çeliköz, N., Erişen, Y., & Şahin, M. (2019). Cognitive learning theories with emphasis on latent learning, Gestalt and information processing theories. *Journal of Educational and Instructional Studies in the World*, 9(3), 18–31.

Chen, C. M., & Kuo, C. H. (2019). An optimized group formation scheme to promote collaborative problem-based learning. *Computers & Education*, 133, 94–115.

Crespo, S., & Harper, F. K. (2020). Learning to pose collaborative mathematics problems with secondary prospective teachers. *International Journal of Educational Research*, 120, Article 101430. https://doi.org/10.1016/j.ijer.2019.05.003

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). SAGE Publications.

Creswell, J. W., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process.* SAGE Publications.

Daneshfar, S., & Moharami, M. (2018). Dynamic assessment in Vygotsky's sociocultural theory: Origins and main concepts. *Journal of Language Teaching and Research*, 9(3), 600–607. https://doi.org/10.17507/jltr.0903.20

Denzin, N. K., & Lincoln, Y. S. (2018). *The SAGE handbook of qualitative research* (5th ed.). SAGE Publications.Fadjarajani, S., As'ari, R., & Putri, A. E. (2024). Model of problem-based learning in geography: Focusing on societal dynamics to enhance spatial thinking skills. *E3S Web of Conferences*, 600, Article 02011. https://doi.org/10.1051/e3sconf/202460002011

Haug, B. S., & Mork, S. M. (2021). Taking 21st century skills from vision to classroom: What teachers highlight as supportive professional development in the light of new demands from educational reforms. *Teaching and Teacher Education*, 100, Article 103286. https://doi.org/10.1016/j.tate.2021.103286

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? *Educational Psychology Review*, 16(3), 235–266. https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Kementerian Pendidikan Malaysia. (2013). *Malaysia Education Blueprint 2013–2025*. Kementerian Pendidikan Malaysia.

Kwan, C. Y. (2019). A thorny path: The developmental course of problem-based learning for health sciences education in Asia. *Advances in Health Sciences Education*, 24, 893–901.

Li, S., Pöysä-Tarhonen, J., & Häkkinen, P. (2023). Students' collaboration dispositions across diverse skills of collaborative problem solving in a computer-based assessment environment. *Computers in Human Behaviour Reports*, 11, Article 100312. https://doi.org/10.1016/j.chbr.2023.100312

Lickona, T., & Davidson, M. (2005). *Smart & good high schools: Integrating excellence and ethics for success in school, work, and beyond*. Center for the 4th and 5th Rs / Character Education Partnership.

Lim, C., & Han, H. (2020). Development in instructional design strategies for integrating an online support system for creative problem solving into a university course. *Asia Pacific Education Review*, 21, 539–552.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry.* SAGE Publications.

Lonergan, R., Cumming, T. M., & O'Neill, S. C. (2022). Exploring the efficacy of problem-based learning in diverse secondary school classrooms: Characteristics and goals of problem-based learning. *International Journal of Educational Research*, 112, Article 101945. https://doi.org/10.1016/j.ijer.2022.101945

Loyens, S. M. M., Magda, J., & Rikers, R. M. J. P. (2008). Self-directed learning in problem-based learning and its relationships with self-regulated learning. *Educational Psychology Review*, 20, 411–427.

Malaysian Nature Society. (n.d.). *Water Vision 2020*. https://www.mns.my/water-vision-programme/water-vision-2020/

Matthews, M. R. (2002). Constructivism and science education: A further appraisal. *Journal of Science Education and Technology*, 11(2), 121–134. https://doi.org/10.1023/A:1015259914523

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation.* John Wiley & Sons.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook* (3rd ed.). SAGE Publications.

Nguyen, L. T. V., Cleveland, D., Nguyen, C. T. M., & Joyce, C. (2024). Problem-based learning and the integration of sustainable development goals. *Journal of Work-Applied Management*, 16(2), 218–234. https://doi.org/10.1108/JWAM-12-2023-0142

OECD. (2018). *Education at a glance 2018: OECD indicators*. OECD Publishing. https://doi.org/10.1787/eag-2018-en

Pakpahan, F. H., & Saragih, M. (2022). Theory of cognitive development by Jean Piaget. *Journal of Applied Linguistics*, 2(2), 55–60. https://doi.org/10.52622/joal.v2i2.79

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Review of Psychology*, 49(1), 345–375. https://doi.org/10.1146/annurev.psych.49.1.345

Piaget, J., & Inhelder, B. (1972). *The psychology of the child* (H. Weaver, Trans.). Basic Books.

Pu, D., Ni, J., Song, D., Zhang, W., Wang, Y., Wu, L., Wang, X., & Wang, Y. (2019). Influence of critical thinking disposition on the learning efficiency of problem-based learning in undergraduate medical students. *BMC Medical Education*, 19, Article 1. https://doi.org/10.1186/s12909-018-1418-5

Pyle, E., & Hung, W. (2019). The role of subject presence type on student motivation in a PBL learning environment. *Advances in Health Sciences Education*, 24, 643–663.

Richards, L. (2015). *Handling qualitative data: A practical guide* (3rd ed.). SAGE Publications.

Routhe, H. W., Holgaard, J. E., & Kolmos, A. (2025). Embedded ethics in problem design: The case of problem-based learning in engineering and science. In *The Routledge International Handbook of Engineering Ethics Education* (pp. 378–391). Routledge. https://doi.org/10.4324/9781003464259-26

Seibert, S. A. (2021). Problem-based learning: A strategy to foster Generation Z's critical thinking and

perseverance. *Teaching and Learning in Nursing*, 16(1), 85–88.

Stake, R. E. (1995). *The art of case study research.* SAGE Publications.

Taylor, T., & Edwards, T. L. (2021). What can we learn by treating perspective taking as problem solving? *Perspectives on Behaviour Science*, 44(2–3), 359–387. https://doi.org/10.1007/s40614-021-00307-w

UNESCO. (2015). *World Education Forum 2015: Final report* (ED.2015/WS/34). UNESCO Publishing.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds. & Trans.). Harvard University Press.

Wibowo, F. C. (2023). Effects of augmented reality integration (ARI) based model physics independent learning (MPIL) for facilitating 21st-century skills (21-CS). *Journal of Technology and Science Education*, 13(1), 178–192. https://doi.org/10.3926/jotse.1800

Yin, R. K. (2011). *Qualitative research from start to finish.* Guilford Press.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). SAGE Publications.