Advanced STEM education through action science enhanced with artificial intelligence

American Journal of Creative Education
Vol. 9, No. 1, 45-60, 2026
e-ISSN: 2706-6088

(Corresponding Author)

William H. Robertson[1]
Juan P. Santana[2]

[1,2]*Teacher Education Department, College of Education, the University of Texas at El Paso, 500 West University, El Paso, Texas, USA.*
[1]*Email:* robertson@utep.edu
[2]*Email:* jpsantana@miners.utep.edu

ABSTRACT

This article explores the integration of Action Science—an experiential STEM approach using extreme sports—with artificial intelligence (AI) to enhance teaching and learning. Action Science employs activities such as skateboarding and BMX, along with multimedia resources, to engage students in real-world applications of STEM concepts through a constructivist framework. The addition of AI technologies, including machine learning, natural language processing, and immersive environments, enables personalized instruction, real-time feedback, and adaptive learning pathways that support diverse learners and improve accessibility. The study highlights how AI can strengthen student engagement and deepen understanding by tailoring content to individual needs, particularly within problem-based and inquiry-based learning environments. These approaches encourage students to ask questions, evaluate evidence, and construct knowledge—skills that align with effective and responsible AI use. AI tools can further enhance these processes by guiding inquiry, recommending resources, and fostering independent learning and digital literacy. However, the article also emphasizes the ethical challenges associated with AI integration, including the risk of reinforcing systemic biases and inequities. It calls for the development of inclusive and equitable frameworks to ensure responsible implementation. Overall, the combination of AI and Action Science offers a promising pathway for creating adaptive, engaging STEM learning environments that promote creativity, critical thinking, and inclusivity while preparing students for a technologically complex world.

Keywords: *Action science, Artificial intelligence, Constructivism, Inquiry, Problem-based learning, Skateboarding.*

DOI: 10.55284/ajce.v9i1.1810

Citation | Robertson, W. H., & Santana, J. P. (2026). Advanced STEM education through action science enhanced with artificial intelligence. *American Journal of Creative Education, 9*(1), 45–60.

Funding: The University of Texas at El Paso, USA, Grant number UTEP-ROB-1-202528

Institutional Review Board Statement: Not applicable.

Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Competing Interests: The authors declare that they have no competing interests.

Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

Disclosure of AI Use: This research document was created through comprehensive revision and synthesis. The original documents utilized AI tools to support manuscript preparation, including: Microsoft Word Copilot for dictation and supplementary image generation. Copilot, ChatGPT, and Gemini for additional image generation and content refinement. Perplexity AI, Julius AI, and Google Colab for data analysis, visualization, and research support. UTEP Library search engines, Google Scholar, and Refworks for literature review and APA 7 style formatting. Grammarly for grammar and syntax review. The authors, bear full responsibility for the content, organization, synthesis, and presentation of this comprehensive work.

History: Received: 18 February 2026/ Revised: 6 April 2026/ Accepted: 15 April 2026/ Published: 23 April 2026
Publisher: Online Science Publishing

Highlights of this paper

- The article explores how integrating Action Science—an approach that uses extreme sports to teach STEM—with artificial intelligence (AI) can create engaging, personalized, and adaptive learning environments.
- It highlights that AI tools such as machine learning and virtual or augmented reality can enhance inquiry-based and problem-based learning by providing real-time feedback, supporting accessibility, and fostering critical thinking, while also raising ethical concerns about bias and equity.
- Ultimately, the article argues that combining AI with Action Science aligns with modern STEM standards by promoting inclusive, student-centered education that encourages creativity, interdisciplinary learning, and real-world application.

1. INTRODUCTION TO ACTION SCIENCE ENHANCED WITH ARTIFICIAL INTELLIGENCE

This article examines the integration of Action Science, a science, technology, engineering and mathematics (STEM) educational approach that uses extreme sports, integrated with artificial intelligence (AI) to enhance learning experiences. By incorporating AI-based tools, educators can personalize learning, support accessibility, and increase engagement while using data to inform professional development. At the same time, AI adoption raises ethical concerns that require inclusive and equitable frameworks. Through the combination of AI and Action Science, this article explores how educators can design adaptive learning environments that support diverse learners and promote creativity and critical thinking.

Action Science is an educational approach that employs extreme sports such as skateboarding and BMX to teach STEM concepts using hands-on activities, videos, and graphic novels. This constructivist design engages students through real-world applications and multimedia resources (Robertson, 2014; Robertson & Tillman, 2024). AI technologies, including machine learning, natural language processing, and virtual or augmented reality, can further personalize instruction by providing real-time feedback, adaptive learning pathways, and assistive tools that support communication and skill development. However, integrating Action Science and AI requires careful attention to ethical considerations and systemic biases. This article examines how AI-supported Action Science can enhance STEM education while maintaining a focus on equity and inclusivity.

AI is transforming STEM education by enabling adaptive interventions tailored to individual learning needs. Technologies such as machine learning, natural language processing, and virtual or augmented reality allow students to explore scientific concepts through interactive and immersive experiences at the intersection of AI and STEM education. Studies by Rai, Sonne, and Kim (2023) and Elkot, Alhalangy, AbdAlgane, and Ali (2025) highlight the potential of AI to foster deeper engagement through personalized lesson plans and structured interactive environments, while also warning that AI systems may reproduce societal biases if they are not designed with inclusivity in mind.

Problem-based learning (PBL), and particularly inquiry-based learning (IBL), positions students to ask questions, investigate, and construct their own understanding, thereby fostering critical thinking and problem-solving skills that are essential for effective use of AI tools. Research indicates that IBL strengthens students' ability to formulate meaningful questions, acquire and evaluate evidence, and generate scientific explanations—skills that align directly with leveraging AI for research, content creation, and problem-solving. Integrating AI into IBL environments further personalizes learning because AI can recommend resources, guide inquiry, and provide tailored feedback, enabling students to navigate complex information more independently while developing adaptability and digital literacy for responsible and creative AI use in academic and real-world contexts (Elkot et al., 2025; Rai et al., 2023).

The Next Generation Science Standards (NGSS) guide STEM education and advocate for inquiry-based instruction that emphasizes conceptual understanding, interdisciplinary connections, and real-world relevance through three-dimensional learning, which includes disciplinary core ideas, science and engineering practices, and crosscutting concepts (National Research Council, 2011). From this perspective, AI-enhanced Action Science aligns with NGSS by combining inquiry-based, student-centered learning with technology-rich, contextually grounded STEM instruction.

1.1. Action Science as a Tool for STEM Learning

Popularized through Dr. Skateboard's Action Science curriculum, this approach engages students with hands-on learning, videos, and graphic novels that illustrate physics and engineering principles through extreme sports. This constructivist design encourages active participation, problem-solving, and collaboration, which are key elements in STEM education. Research indicates that students respond positively to kinesthetic learning experiences, making Action Science a useful strategy for learners with diverse styles. The curriculum is structured around a five-phase 5E model—engagement, exploration, explanation, elaboration, and evaluation—which supports iterative concept development (Robertson, 2014; Robertson & Tillman, 2024).

Action Science best practices and resources emphasize experiential learning through guided practice and instruction. The curriculum offers free Open Educational Resources (OER), including demonstration videos and classroom activities designed to support middle school students' understanding of core physical science ideas. These materials are hosted on Dr. Skateboard's YouTube channel and are intended for classroom integration. In addition, Action Science incorporates graphic novels as key instructional tools. Dr. Skateboard's Action Science comics use skateboarding and BMX contexts to teach physics concepts such as forces, motion, simple machines, and Newton's laws, and they are available in full-color English and Spanish editions to make science more accessible and engaging for students, families, and educators (Robertson, 2014; Robertson & Tillman, 2024).

1.2. Elements for AI Integration in STEM Education

Tammets and Ley (2023) argue that current pedagogical practices have not yet fully leveraged AI technologies, underscoring the need for meaningful integration into teaching. At present, AI primarily supports lesson planning, content delivery, classroom monitoring, and teacher reflection, while also assisting educators who struggle with classroom management and enabling adaptive, student-centered learning. Their work suggests that involving teachers in the design of AI solutions is essential so that AI strengthens professional vision rather than dictating instructional choices.

The theoretical foundations of AI integration emphasize enhancing teachers' ability to notice and make informed decisions about classroom events. Teacher professional vision and knowledge-based reasoning involve selectively attending to classroom cues, interpreting them using pedagogical and content knowledge, and predicting likely outcomes. Within a framework informed by Shulman (1987) categories of content knowledge, pedagogical knowledge, and pedagogical content knowledge, AI-supported professional development can foster experiential learning cycles in which teachers engage in concrete experiences with AI tools, conduct reflective analysis, connect practice to theory, and experiment with new strategies.

In this model, teachers design problem-solving tasks using AI-enhanced learning tools and collect classroom data through AI dashboards. Regular collaborative sessions help educators develop shared understandings of student learning by interpreting data, recognizing pedagogical cues, and linking those cues to student outcomes. As a result, teachers strengthen the connections among pedagogical knowledge, AI applications, and student-centered instruction, aligning their practices with competency standards and improving adaptive decision-making.

Seidel and Stürmer (2014) distinguish between noticing and reasoning as core components of teachers' professional vision. Noticing refers to selective attention to classroom information, whereas reasoning involves describing, explaining, and predicting events based on pedagogical and domain-specific knowledge. Co-creation and co-design processes, as discussed by Gazulla, Bauters, Hietala, Leinonen, and Kapros (2020) further support technology-enhanced learning by engaging educators in collaboratively producing artifacts and aligning AI tools with user-centered design principles so that they remain relevant and useful in authentic classroom contexts.

Human-centered AI design prioritizes teacher agency and positions technology as an enabler rather than a determinant of instruction. Gazulla, Bauters, Hietala, Leinonen, and Kapros (2020) emphasizes that AI should support human learning, trust-building, and collaborative engagement instead of replacing essential instructional roles. In this view, AI integration encourages empathy, thoughtful decision-making, and data-informed teaching practices that reinforce, rather than diminish, educators' professional judgment.

Tammets and Ley (2023) conceptual model illustrates these ideas through a case study of 26 Estonian primary mathematics teachers who applied AI-supported frameworks to teach fractions and financial literacy. Teachers used AI dashboards to analyze classroom data, design AI-enhanced lesson plans, and interpret student learning patterns. Findings indicate that this approach strengthened links between AI tools, pedagogy, and student-centered instruction, improved teachers' ability to perceive student needs, and supported adaptive teaching strategies aligned with learning objectives, thereby enhancing instructional quality and teacher competencies.

1.3. Importance of Constructivism and Inquiry-Based Instruction

Inquiry-based learning plays an important role in STEM and physics education by supporting active exploration, critical thinking, and problem-solving. Within Dr. Skateboard's Action Science curriculum, inquiry underpins meaningful discovery as students construct knowledge through hands-on experimentation and structured activities. Video demonstrations, such as the Simple Machines episode, introduce core ideas and prepare learners for interactive tasks like "Skateboards Have Levers and Fulcrums," which reinforce Newton's laws of motion and energy transfer (National Research Council, 2011).

However, not all inquiry-based activities contribute equally to scientific literacy. Oliver, McConney, and Woods-McConney (2021) found that practices such as asking students to explain their ideas, participate in debates, or construct arguments about science questions had limited impact when they were not grounded in strong subject-matter foundations. These activities may increase engagement but can lack the depth needed to foster substantial scientific understanding.

As a counterpoint, Oliver et al. (2021) reported that practical experiments and drawing conclusions from those experiments were more effective in enhancing scientific literacy. Their study identified a non-linear relationship between the frequency of STEM activities and literacy outcomes, with the most effective approach involving infrequent but carefully selected tasks. This pattern underscores the need for balanced curriculum design in which activities are deliberately aligned with disciplinary knowledge and meaningful literacy goals.

De Jong, Linn, and Zacharia (2023) argue that inquiry-based instruction and direct instruction each have distinctive strengths, and their effectiveness depends on factors such as learning goals, disciplinary domain, and students' prior knowledge and characteristics. Inquiry can foster deeper conceptual understanding, whereas direct instruction may better prevent misconceptions. From this perspective, they advocate a balanced approach that strategically combines both modes of teaching.

Responding to this debate, Sweller, Ayres, and Kalyuga (2024) propose that an effective combination of inquiry-based learning and explicit instruction can be guided by evolutionary psychology and cognitive load theory. Cognitive load theory explains how working memory processes information and emphasizes the limits of capacity and duration across intrinsic, germane, and extraneous loads. Sweller et al. (2024) describe a post-constructivist view in which humans acquire information through inquiry and problem-solving ("randomness as genesis") and through explicit instruction from others ("borrowing and reorganizing"), with explicit instruction enabling rapid knowledge transfer and inquiry promoting exploration and interdisciplinary connections. A balanced design that pairs explicit guidance with practice aligns with cognitive load theory and can improve learning outcomes.

Further inquiry-based extensions can deepen understanding and skill development within Action Science. For example, an activity in which students design a simple machine using a lever and fulcrum to launch a marshmallow encourages iterative problem-solving and engineering creativity. Such tasks integrate the scientific method, strengthen students' self-efficacy in scientific reasoning, and promote engagement in authentic STEM applications, supporting long-term retention and interdisciplinary problem-solving (Robertson & Tillman, 2024).

In-service science teacher professional development increasingly incorporates constructivist methods that emphasize active learning and institutional support. Effective professional development programs attend to classroom dynamics, integrate leadership, and prioritize sustained, student-centered learning. These designs foster engagement, participation, and higher-order thinking through activities such as discussion, problem-solving, and collaboration, distinguishing them from traditional lecture-based approaches (De Jong et al., 2023; Gerard, Spitulnik, & Linn, 2010; Sweller et al., 2024; Yang, Asselin, & Osgood, 2018, 2020). Within this context, combining cognitive load theory with AI-informed pedagogical content knowledge (AI-PCK) is recommended to support in-class active learning that brings students into their zone of proximal development through assistance, collaboration, and interaction as integral aspects of direct instruction and learning by doing (Bowen & Watson, 2024; Robertson, 2014).

1.4. AI-Enhanced Action Science: Practical Implementation Approaches

Combining inquiry-based and direct instruction has been shown to be effective when adapted to specific learning goals, disciplinary contexts, and student characteristics. Structured inquiry cycles invite learners to explore, question, and construct understanding, while explicit teaching helps stabilize core ideas and reduce misconceptions. Successful implementation of this balanced approach depends on comprehensive teacher preparation, supportive classroom environments, and intentional integration of technological resources. Active learning and inquiry-based instruction together can enhance student engagement, critical thinking, and academic achievement by promoting self-directed learning in technology-rich settings (Sweller et al., 2024; Yang et al., 2018, 2020).

Incorporating AI into Action Science adds several advantages for STEM education. Adaptive learning technologies allow AI systems to personalize Action Science lessons by adjusting content to students' progress and needs. Interactive simulations, including augmented reality (AR) and AI-driven models, offer real-world physics applications that enrich students' experiences with motion, forces, and energy. AI-based speech recognition and text-to-speech tools increase multimodal accessibility, broadening participation for diverse learners, while AI-supported assessments provide real-time feedback that helps educators tailor instruction and interventions more precisely.

The benefits of AI-enhanced Action Science can be summarized in several key areas. First, AI supports learning experiences that feel personalized to individual students. Second, it enables dynamic adjustment of physics problem complexity to match learners' developing skills. Third, real-time motion analysis in skateboarding and BMX fosters engagement by connecting abstract concepts to visible performance data. Fourth, immersive simulations allow students to actively investigate force and energy concepts. Fifth, AI-powered tutoring tools help identify knowledge gaps, guide inquiry, and provide targeted support. Finally, AI contributes to teacher professional development through community-driven platforms that recommend tutorials, collaboration opportunities, and engagement analytics, helping educators refine instructional strategies and sustain motivation for STEM learning (Bowen & Watson, 2024; Robertson, 2014; Robertson & D. Tillman, 2024).

1.5. Ethical and Structural Challenges of AI in STEM Education

Despite its potential, AI in STEM education presents significant ethical and structural challenges. AI integration in pedagogical content knowledge (PCK) and teacher professional development is often framed optimistically even though secure learning environments remain underdeveloped and risks persist, including prematurely categorizing students instead of supporting them through scaffolding. Bias in AI models is a continuing concern because tools trained on mainstream educational data can unintentionally reinforce exclusionary practices (Bennett & Keyes, 2020). Extensive data collection for AI-driven applications also raises privacy issues related to consent and security (Almufareh, Ahmad, Pervez, & Iftikhar, 2024). Additionally, AI-enhanced tools may disproportionately benefit students with greater access to technology, potentially widening existing educational inequities (Connor, 2019; Kramarczuk Voulgarides et al., 2024).

To support equitable AI integration in Action Science and broader STEM education, several areas require further investigation. Expanding AI applications into early STEM education could help create AI-supported curricula for younger learners that incorporate culturally responsive and multilingual content. Longitudinal studies are needed to examine the long-term educational and social effects of AI-based Action Science interventions. Addressing equity and bias in AI tools is essential for building inclusive practices that confront systemic disparities. Teacher training and professional development must also prepare educators to use AI-enhanced Action Science effectively in diverse classrooms. Ethical AI development in education requires transparent governance policies that protect student data and ensure responsible use. By tackling these concerns while leveraging AI's capabilities, Action Science can function as a model for technology-rich STEM instruction that promotes engagement, critical thinking, and more equitable access to high-quality learning opportunities.

Adaptive learning systems further enhance the teaching of physics through extreme sports by tailoring lessons, offering real-time feedback, and embedding interactive simulations. By adjusting content to individual students' abilities, these platforms help learners connect abstract physics ideas—such as momentum, force, and rotational motion—to real movements in skateboarding, BMX, and related sports. For example, students can analyze how skateboarders use momentum in tricks or manage rotation in midair, making physics concepts more concrete and engaging. This approach supports motivation, fosters independent learning, and strengthens comprehension and retention of complex content (Robertson, 2014; Robertson & Tillman, 2024).

1.6. AI Adoption in Schools: Key Factors and Considerations

Recent research on AI adoption in education highlights the central roles of funding, infrastructure, teacher training, and policy alignment, while also identifying gaps in K–12 implementation, ethical frameworks, and detailed funding models needed for equitable and sustainable AI use. Julius (2025) synthesized these elements in a graph illustrating the main influences on AI adoption in schools (see Figure 1). Reports from the U.S. Department of Education and the Consortium for School Networking emphasize that limited funding is a major barrier to acquiring and maintaining AI technologies. Findings from the International Society for Technology in Education and the RAND Corporation underscore the importance of teacher professional development for effective AI integration. Infrastructure also shapes adoption; surveys from Education Superhighway and CoSN document how gaps in connectivity and access to devices hinder AI implementation.

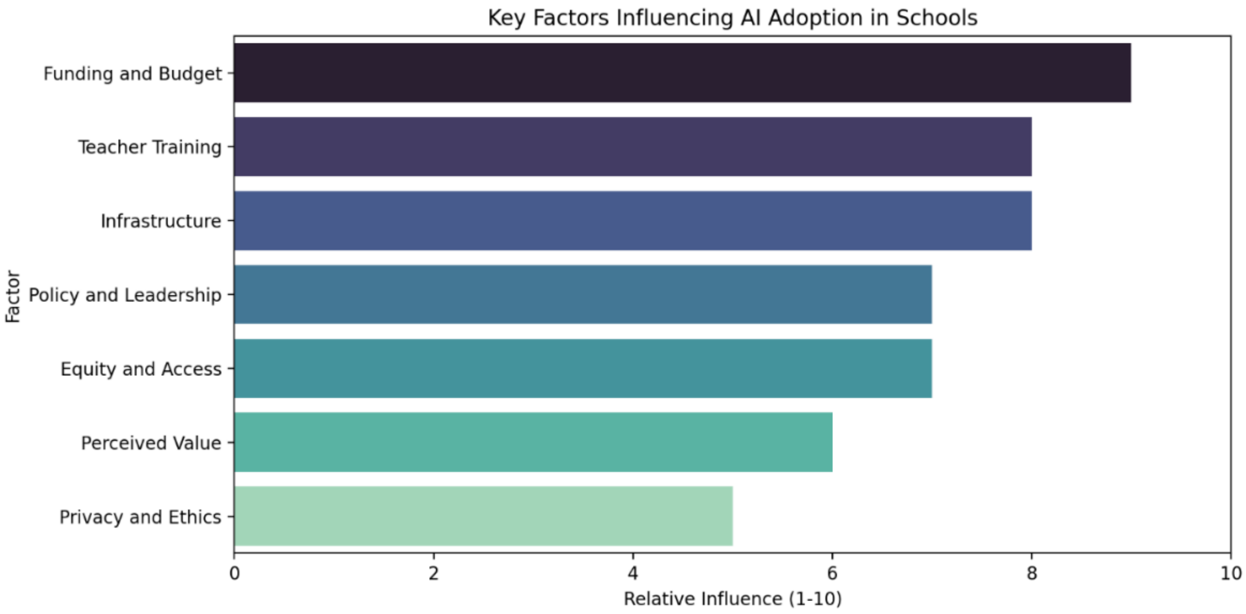

Figure 1. Key factors influencing adoption of AI in US schools.

Policy and leadership influence AI uptake at state and district levels, as shown in studies from the Brookings Institution and the U.S. Department of Education's Office of Educational Technology. The Digital Equity Act and reports from the National Center for Education Statistics address persistent disparities in access, underscoring the need for equitable distribution of AI-related resources. Research from EdTech Impact and the Bill & Melinda Gates Foundation indicates that educators' perceptions of AI's benefits—such as improved efficiency and learning outcomes—affect adoption rates. At the same time, organizations like the Future of Privacy Forum and the Center for Democracy & Technology call attention to student data privacy and ethical issues, reinforcing the necessity of responsible AI use in education (Julius, 2025).

1.7. Extreme Sports as Physics Teaching Tools

Extreme sports offer a practical, engaging context for teaching physics concepts through real-world motion. Skateboarding illustrates momentum, rotational motion, center of gravity, and force during tricks and jumps, while also involving friction, balance, angular momentum, and projectile motion as riders move along ramps or perform aerial maneuvers. BMX highlights inertia, centrifugal and centripetal forces, and energy transfer, particularly in jumps and stunts. Parkour and rock climbing emphasize gravity, friction, specific weight, and mechanical advantage in climbing techniques, while jumping sequences demonstrate potential and kinetic energy, mechanical energy, gravity, and acceleration. Integrating these activities into physics education helps students connect abstract principles to bodily experience, making learning more immersive and memorable.

1.8. Suggestions for an Action Science "Mobile Museum" Suite

The proposed Action Science "mobile museum" suite is designed as an interactive environment that connects STEM, physics, and AI through physical demonstrations, inquiry-based learning, AI-driven simulations, and live experiments. Its purpose is to inspire students with extreme sports physics while incorporating digital tools for hands-on exploration. The museum room centers on Action Science as an approach that uses skateboarding and BMX to teach STEM concepts through real-world applications, multimedia resources, and active learning. AI-driven technologies in this space will personalize instruction, provide real-time feedback, and support adaptive learning environments.

The suite includes three main immersive stations: (a) interactive simulations with AI integration, (b) a live skateboarding demonstration, and (c) a workshop area. The Action Science AR/VR Video Lab serves as an entry point where secondary students engage with core physics concepts through extreme sports in augmented reality and AI-powered simulations. The lab integrates the WISE platform from the University of California, Berkeley, as a model for inquiry-based, interactive science learning (WISE, 2026). Touchscreens provide access to interactive Action Science games that allow students to manipulate variables related to motion, gravity, and force in a controlled digital environment. Evidence from Ton De Jong, Linn, and Zacharia (2013) indicates that simulations and digital experimentation can strengthen conceptual understanding in physics, supporting the design of this lab.

1.9. Live Skateboarding Demonstration and Physics in Motion

The main section of the Action Science museum suite features a performance zone where a professional skateboarder demonstrates tricks that illustrate Newton's laws of motion and related physics concepts. When adapted, this space can also host parkour and rock-climbing demonstrations that highlight gravitational forces, friction, and mechanical advantage. Motion tracking and AI analysis provide real-time breakdowns of each maneuver so that visitors can see how scientific principles apply to skateboarding, climbing, and obstacle navigation.

Using Julius (2025) the authors designed a dashboard to monitor Newton's laws during a skateboard demonstration with embedded sensors. (see Figure 2) The simulation models the first law of motion (inertia) by showing the board continuing to move after the applied force stops at $t = 5$ seconds, with friction causing gradual deceleration. The second law, $F = ma$, is represented by a 4 N applied force acting on a specified mass, and the third law (action–reaction) appears in the interaction between the skateboarder's push and frictional forces (see Table 1).

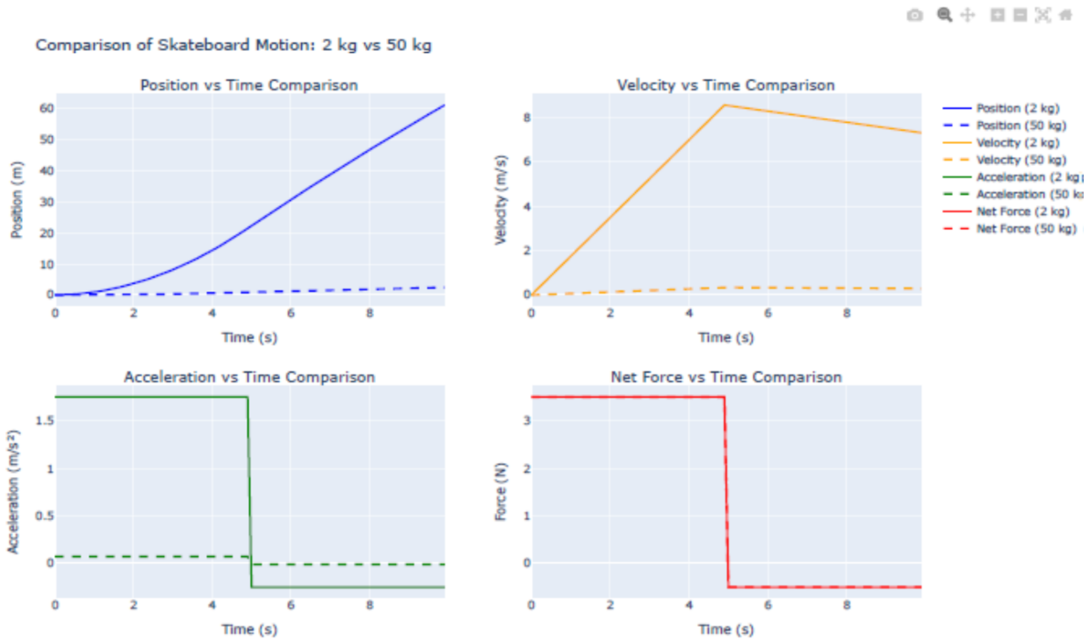

Figure 2. Comparing trajectories, mass and Newton Laws in real time.

Table 1. Data set of skateboard trajectories.

Time (s)	Position _2kg (m)	Position_ 50kg (m)	Velocity_2kg (m/s)	Velocity_50kg (m/s)	Acceleration_2kg (m/s²)	Acceleration_50kg (m/s²)
0	0	0	0	0	1.75	0.07
0.1	0.0175	0.0007	0.175	0.007	1.75	0.07
0.2	0.0525	0.0021	0.35	0.014	1.75	0.07
0.3	0.105	0.0042	0.525	0.021	1.75	0.07
0.4	0.175	0.007	0.7	0.028	1.75	0.07

Four plots support analysis: (a) position versus time, (b) velocity versus time, (c) acceleration versus time, and (d) net force versus time. The model assumes a total mass of 2 kg, a 4 N driving force, 0.5 N friction, a 5-second push, and a 10-second total simulation interval. A second simulation with a 50 kg combined mass, the same applied force, and identical friction demonstrates substantially reduced acceleration, slower velocity growth, and altered position curves, illustrating the direct relationship between mass and acceleration in Newton's second law (Julius, 2025). These dashboard-based visualizations offer an engaging way to explore Newtonian motion in real time.

1.10. Action Science Workshops Area and Mobile Lab

The Action Science museum suite includes workshop areas that immerse children in STEAM-oriented activities. In the skateboard design and engineering workshop, participants engage in tinkering, prototyping, and 3D printing to create custom boards, with AI tools assisting in optimizing designs for performance and durability. Additional AI and robotics demonstrations use toy skateboards fitted with motion sensors, platforms such as Physio or Arduino, and real-time data displays to illustrate speed, acceleration, rotational forces, torque, and motion control. Children also construct small robotic mechanisms with levers and fulcrums to develop an intuitive understanding of mechanical engineering.

A build-a-ramp station invites visitors to design mini ramps for skateboards and BMX bikes using AI-assisted modeling tools. Through inquiry-based challenges, teams optimize launch angles and consider gravitational force and energy transfer. AI-driven accessibility tools (speech-to-text, translation, text-to-speech), sensory-friendly displays, and tactile activities support diverse and neurodiverse learners. Overall, the suite aims to (a) enhance STEM curiosity by connecting science and action sports, (b) promote inquiry-based learning through hands-on challenges, AI tools, and live data capture, and (c) foster engineering creativity as students design, test, and refine ideas using scientific principles. With AI integration, the Action Science curriculum can address motion, energy, electricity, waves, thermodynamics, and modern physics through demonstrations, workshops, data analysis, motion tracking, and predictive modeling.

An alternative design is the Action Science mobile lab, modeled on existing STEM mobile labs widely used in U.S. school districts (see Table 2). These labs increase literacy and engagement through hands-on, inquiry-based learning (Rawat, Elahi, & Kumar, 2023) introduce robotics and 3D printing, and improve attentiveness and sustained STEM interest (Beier et al., 2019). They also help reduce resource and transportation barriers in underserved communities by bringing authentic laboratory experiences to students (Jones, Chang, Carter, & Roden, 2019). Studies show that mobile labs can foster STEM identity and vocational aspirations in culturally responsive environments, and the availability of multiple vendors makes customized designs feasible (Beier et al., 2019; Society of Women Engineers, 2024).

Table 2. Action science demonstration/Workshops per topic.

Physics Topic	Action Science Demonstration/Workshop	AI Integration
Motion & Forces	Skateboard ramp jumps demonstrating acceleration, velocity, and Newton's Laws. BMX track analysis of centripetal force during turns.	Use AI motion-tracking apps (e.g., Coach's Eye) to analyze skateboard/BMX videos. Students train ML models to predict trajectory based on force variables[24].
Energy & Work	BMX hill climbs to study kinetic/potential energy. Skateboard ollies to calculate work done against gravity.	AI simulations (Python or PhET) modeling energy conservation. Students use regression models to correlate ramp height with kinetic energy output[45].
Electricity & Magnetism	Build LED-lit skateboard circuits to explore voltage/current. Electromagnetic brake demonstrations using BMX bike wheels and magnets.	Neural networks (Google Teachable Machine) to optimize circuit designs. AI analysis of magnetic field data from Arduino sensors during braking experiments.
Waves & Optics	Analyze sound waves from skateboard wheel friction. Mirror-based trick setups (e.g., laser reflections) to study light properties.	AI audio tools (e.g., Audacity + ML plugins) to measure frequency/amplitude. Computer vision (OpenCV) to track light reflection paths in optical experiments[3].
Thermodynamics	Friction heat measurements during skateboard grinding. Insulation experiments with BMX gear in varying temperatures.	Thermal camera data analyzed via AI to predict heat dissipation patterns. Python scripts modeling entropy changes in closed systems[15].
Modern Physics	Skateboard quantum tunneling analogies using obstacle navigation. Radioactive decay simulations with action sports timelapse videos.	AI-generated simulations (GANs) of relativistic motion at high speeds. Quantum computing platforms (IBM Qiskit) to model atomic structures in skateboard materials[3].

1.11. K–12 Teachers' Professional Development with AI-Enhanced Action Science

Effective professional development (PD) for in-service teachers depends on collaboration, clear expectations, and adequate resources, balancing direct instruction and inquiry-based learning to support STEM interest, engagement, and real-world applications (Southard, Christen, & Gupta, 2024). Recent work on AI adoption reiterates the importance of funding, infrastructure, teacher training, and policy coordination, while noting persistent gaps in K–12 AI integration and ethical guidance. Classroom challenges include teachers limited technical skills compared with students' enthusiasm for technology, low motivation among some in-service teachers, insufficient institutional support, and ongoing privacy and ethics concerns. These factors signal the need for tailored, hands-on, ongoing AI-focused PD that addresses both enabling and inhibiting conditions; without such support, AI's potential to personalize learning and enhance teaching effectiveness remains constrained (Michaeli, Kroparo, & Hershkovitz, 2020).

The AI-enhanced Action Science suite can support both short-term professional development during visits and longer-term PD through structured training sessions. Its participatory design strengthens teacher engagement and instructional practice, while collaborations between researchers and teachers refine professional vision and align AI tools with effective pedagogy (Tammets & Ley, 2023). Integrating AI into student-centered teaching helps educators identify pedagogical cues and apply knowledge-based reasoning, fostering innovation that combines AI with established instructional methodologies.

For example, after a museum or lab visit, educators can receive Action Science toolkits—both virtual and one-page formats—with suggestions for AI–Action Science coursework. More comprehensive workshops can draw on emerging classroom-centered AI curricula tied to national AI induction efforts (Tammets & Ley, 2023; Wang et al., 2023; Yang et al., 2020). Dashboards, already common for monitoring student progress and assessment, are increasingly used to support teacher learning by providing data that informs professional growth and leadership development (Michaeli et al., 2020).

A sample dashboard (see Figure 3) generated with Perplexity (2025) models 12 teachers participating in the first year of a two-year AI–Action Science PD program in secondary physics. It includes (a) color-coded bar charts tracking attendance and curriculum fidelity, (b) a heatmap of AI task usage, (c) an interactive line chart of mastery gains over 20 weeks, and (d) a histogram of teacher-reported confidence with AI tools, plus a summary panel offering actionable recommendations for PD coordinators. Perplexity AI suggested platforms such as Power BI, Tableau, Google Data Studio, and Python (Dash/Plotly) for dashboard construction, and recommended a Google Colab implementation to accommodate coding limitations while preserving analytical functionality.

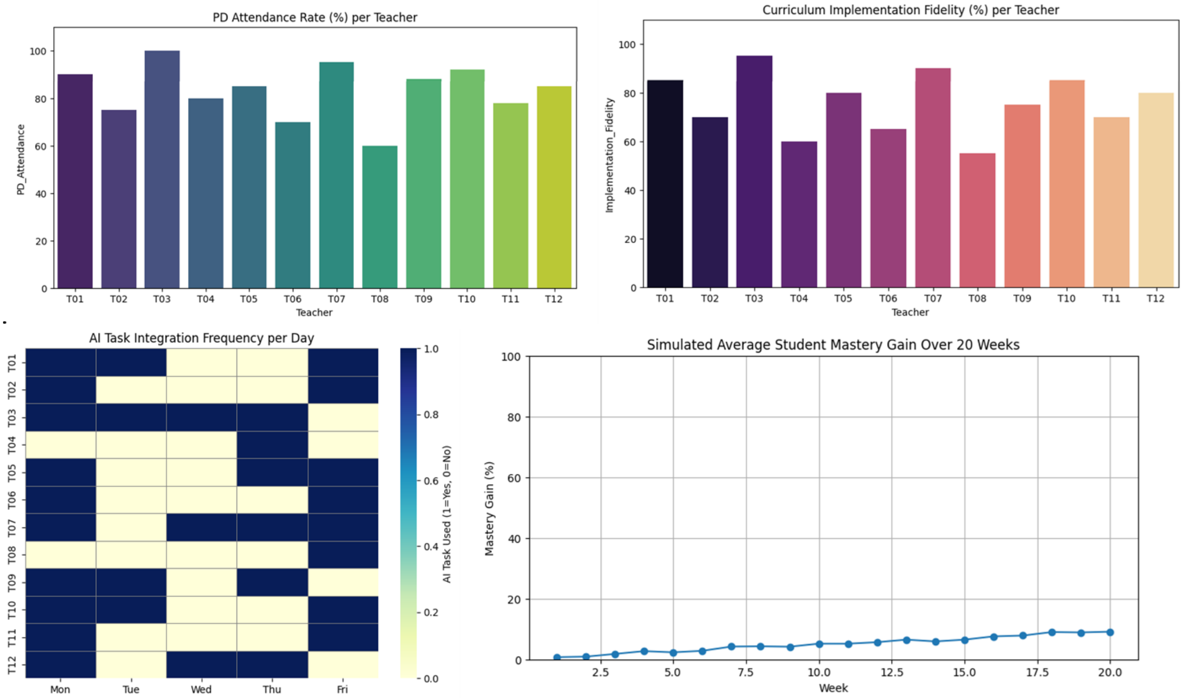

Figure 3. Action science professional development dashboard simulation.

1.12. Teacher Professional Development and Learner-Centered Approaches

Transforming STEM pedagogy requires sustained professional learning. Effective professional development is grounded in exemplary practice, balances structured learning with inquiry into one's own classroom, and supports teachers in integrating technology and differentiated instruction in ways that serve diverse learners (Courduff, Szapkiw, & Wendt, 2016; Duan & Zhao, 2024). Adaptations of lesson study for community college mathematics instructors show how faculty can collaboratively design, test, and refine lessons that emphasize conceptual understanding and problem solving, particularly in developmental and gateway courses (Adapting lesson study, 2019). Regional collaborative initiatives to broaden participation in STEM community college teaching focus on preparing and mentoring faculty to practice inclusive, student-centered pedagogy aligned with Social Cognitive Career Theory supporting local peer mentoring with social equity goals (Broadening Participation in STEM Community College Teaching, 2025).

For adult and postsecondary learners with weak or missing foundations, reforms such as math pathways, summer bridge programs, and open educational resources -based STEM curricula in adult education seek to redesign early learning experiences around coherent, skills-based sequences and contextualized problem solving such as Education Commission of the States (2019); New math pathways for adult learners (2024); OER STEM Project (2024). These initiatives emphasize employer engagement, competency-based assessments, targeted supports, and alignment with learners' educational and career goals. They provide important design precedents for professional development projects that help STEM teachers rethink both content and pedagogy for underprepared learners (Starobin, Schenk, & Laanan, 2018).

1.13. STEM Education Grounded Activities for Action Science Integration

STEM can be a powerful set for resilience, identity formation, and critical engagement with the world. Problem-based and inquiry-based STEM experiences require learners to tolerate ambiguity, persist through trial and error, and revise their thinking, cultivating lifelong learning (Capraro & Slough, 2013; William H Robertson, 2022). Recreational and action-based activities—such as extreme sports physics, outdoor fieldwork, and kinesthetic STREAM projects—demonstrate that rigorous conceptual learning can coexist with fun, embodiment, and joy (Robertson & Tillman, 2024; Yoh, Kim, Chung, & Chung, 2021). Furthermore, critical and place-based pedagogies show how STEM can be reoriented toward local ecologies, histories, and socio-economic realities, enabling students to see themselves as investigators of both natural and social systems (Brickell, 2012; Gruenewald, 2003; Todd, Atchison, & White, 2023).

Resilience, however, should not be reduced to individual grit. DisCrit and related frameworks argue that resilience must be understood at the intersections of race, dis/ability, and other identities, and that educational systems often demand "resilience" from marginalized students without transforming the structures that produce harm (Annamma et al., 2023; Connor, Ferri, & Annamma, 2016). Critical pedagogy in science education responds by advocating for dialogic, problem-posing approaches in which students interrogate both scientific phenomena and the social relations that shape their lives (Aksakalli, 2018; Freire, 2021). In such classrooms, resilience involves not only persisting in the face of challenge but also developing critical consciousness and collective agency.

Recreation and fun activities offer potent contexts for enacting this more expansive resilience. Yoh et al. (2021) argue that integrating experiential, artistic, fun, interactive, and instructive recreation into STREAM (adding arts and recreation to the STEM acronym) can reduce problem-solving stress, promote team building, and support conceptual learning. This approach reinforces that resilience in STEM is relational and structural rather than purely individual. When difficulty is reimagined as such, STEM classrooms can become spaces where students learn not only disciplinary content but also how to act critically and collaboratively in a complex world.

2. CONCLUSION

The Action Science curriculum as defined in this approach offers an attractive framework for introducing students and educators to AI-powered adaptive learning by embedding real-world, project-based experiences that support engagement and contextual understanding (Robertson, 2014). Much educational research is still grappling with AI's disruptive impact on coursework, assignments, and scaffolding, and institutional resistance persists due to concerns that AI might encourage student passivity. At the same time, labor market demands for efficiency and rapid STEM learning point to the need for tools that accelerate comprehension via direct instruction. Action Science instruction is grounded in constructivist, inquiry-based learning yet focuses on germane knowledge and community practice, balancing experiential work with theoretical understanding (Robertson & Tillman, 2024; Sweller et al., 2024).

Significant gaps remain in research on lesson planning that meaningfully integrates AI-informed pedagogical content knowledge (AI-PCK) in STEM education, limiting guidance on designing AI-enhanced instruction aligned with specific content and pedagogy (Rawat et al., 2023). There is also limited exploration of AI-PCK STEM lessons on mobile devices, despite the potential of augmented reality to extend laboratory experiences into homes and communities (Bowen & Watson, 2024; Robertson, 2014; Society of Women Engineers, 2024). Addressing these gaps is crucial for advancing personalized, accessible STEM education that uses AI and mobile technologies to support diverse learning environments.

Dashboards are emerging as powerful visual tools for PD, providing real-time, actionable insights that aid progress monitoring and program evaluation (Michaeli et al., 2020). Nonetheless, some educators remain wary of extensive monitoring. To maintain global competitiveness, the United States must accelerate AI-enhanced education initiatives as countries such as China and Estonia develop national strategies for AI proficiency (Manni, 2020; Wang et al., 2023; Yang et al., 2020). Schools and universities function as testing grounds for AI tools and integrated systems while generating new AI applications. This work was completed with guidance from Robertson (2022) who encouraged the exploration of AI in educational development and highlighted future directions, including AI-PCK integration in STEM lesson design and expanded use of mobile, AR-supported STEM experiences (Rawat et al., 2023; Society of Women Engineers, 2024).

Finally, this approach to STEM responds to emerging student identities in a digital age. Action Science AI integration goes beyond the use of novel technology, and offers learning grounded in lived experience as part of the Action Science museum suite in the form of proposed programming design supporting students and educators' interests. As learners navigate ubiquitous technology, many experience both the affordances and limitations of screen-based instruction. Some express fatigue with passive digital consumption and seek embodied, lived experiences that allow them to “get into” the material world, question conventional knowledge, and develop practical and relational skills. Action Science capitalizes on this by designing challenging tasks that require physical engagement, social interaction, and critical inquiry, rather than isolating students in front of devices.

REFERENCES

Adapting lesson study. (2019). *Adapting lesson study*. Retrieved from https://www.lessonstudy.co.uk/

Aksakalli, A. (2018). The effects of science teaching based on critical pedagogy principles on the classroom climate. *Science Education International*, *29*(4), 233–239.

Almufareh, M. F., Ahmad, Z., Pervez, A., & Iftikhar, M. (2024). *Edge computing-enhanced machine learning framework with anomaly detection-aware predictive modelling in iot healthcare systems.* Paper presented at the In 2024 26th International Multi-Topic Conference (INMIC) (pp. 1-6). IEEE.

Annamma, S. A., Connor, D., Ferri, B., Taylor, E., Gillborn, D., & Ladson-Billings, G. (2023). *Dis/ability critical race studies (DisCrit): Theorizing at the intersections of race and dis/ability. In *Dis/ability critical race studies (DisCrit): Theorizing at the intersections of race and dis/ability** (3rd ed.). London, UK: Routledge.

Beier, M. E., Kim, M. H., Saterbak, A., Leautaud, V., Bishnoi, S., & Gilberto, J. M. (2019). The effect of authentic project-based learning on attitudes and career aspirations in STEM. *Journal of Research in Science Teaching, 56*(1), 3-23. https://doi.org/10.1002/tea.2146

Bennett, W., & Keyes, O. (2020). A hazard of new navigation: Race, reproduction, and redlining on the algorithmic road. *First Monday, 25*(9), e02599.

Bowen, J. A., & Watson, C. E. (2024). *Teaching with AI: A practical guide to a new era of human learning**. Baltimore, MD: Johns Hopkins University Press.

Brickell, K. (2012). 'Mapping'and 'doing'critical geographies of home. *Progress in Human Geography, 36*(2), 225-244. https://doi.org/10.1177/0309132511418708

Broadening Participation in STEM Community College Teaching. (2025). Community College Journal of Research and Practice.

Capraro, R. M., & Slough, S. W. (2013). *Why PBL? Why STEM? Why now? An introduction to STEM project-based learning. In *STEM project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach.* Rotterdam, Netherlands: Sense.

Connor, D. J., Ferri, B. A., & Annamma, S. A. (2016). *DisCrit—Disability studies and critical race theory in education.* New York: Teachers College Press.

Connor, K. (2019). Why are some students excluded from online learning? *Disability Studies Quarterly, 39*(4), 10–15.

Courduff, J., Szapkiw, A., & Wendt, J. L. (2016). Grounded in what works: Exemplary practice in special education teachers' technology integration. *Journal of Special Education Technology, 31*(1), 26-38.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science, 340*(6130), 305-308.

De Jong, T., Linn, M. C., & Zacharia, Z. C. (2023). Inquiry-based learning and direct instruction: Balancing approaches. *Educational Research Review, 32*, 100123.

Duan, H., & Zhao, W. (2024). The effects of educational artificial intelligence-powered applications on teachers' perceived autonomy, professional development for online teaching, and digital burnout. *International Review of Research in Open and Distributed Learning, 25*(3), 57-76.

Education Commission of the States. (2019). *Developmental education: An introduction for policymakers. Education Commission of the States.* Retrieved from https://www.ecs.org/developmental-education-an-introduction-for-policymakers/

Elkot, M. A., Alhalangy, A., AbdAlgane, M., & Ali, R. (2025). Pedagogical influence of AI-chatbots on learning outcomes: A systematic review. *International Journal of Educational Methodology, 11*(4), 527-540.

Freire, P. (2021). *Pedagogy of hope: Reliving pedagogy of the oppressed.* New York: Bloomsbury Academic.

Gazulla, E. D., Bauters, M., Hietala, I., Leinonen, T., & Kapros, E. (2020). Co-creation and co-design in technology-enhanced learning: Innovating science learning outside the classroom. *Id&a Interaction Design & Architecture (s), 42*, 202-226.

Gerard, L. F., Spitulnik, M., & Linn, M. C. (2010). Teacher use of evidence to customize inquiry science instruction. *Journal of research in Science Teaching, 47*(9), 1037-1063. https://doi.org/10.1002/tea.20367

Gruenewald, D. A. (2003). The best of both worlds: A critical pedagogy of place. *Educational Researcher, 32*(4), 3-12.

Jones, A., Chang, A., Carter, R., & Roden, W. (2019). Impacts of hands-on science curriculum for elementary school students and families delivered on a mobile laboratory. *Journal of STEM Outreach*, *2*(1), 1-12.

Julius, A. (2025). *AI for data analysis and modeling*. Retrieved from https://www.julius.ai

Kramarczuk Voulgarides, C., Cruz, R., Strassfeld, N., Aylward, A., Ahram, R., & Firestone, A. (2024). Understanding policy reverberations across the educational ecosystem to effectuate change. *Theory into Practice*, *63*(4), 457-468.

Manni, M. (2020). *Estonians are building the school of tomorrow. Invest in Estonia*. Retrieved from https://investinestonia.com/estonians-are-building-the-school-of-tomorrow/

Michaeli, S., Kroparo, D., & Hershkovitz, A. (2020). Teachers' use of education dashboards and professional growth. *International Review of Research in Open and Distributed Learning*, *21*(4), 61-78. https://doi.org/10.19173/irrodl.v21i4.4663

National Research Council. (2011). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

New math pathways for adult learners. (2024). *New math pathways for adult learners*. Retrieved from Competency-Based Education Network: https://www.cbenetwork.org

OER STEM Project. (2024). *Adult education and literacy. LINCS Literacy Information and Communication System*. Retrieved from https://lincs.ed.gov

Oliver, M. C., McConney, A., & Woods-McConney, A. (2021). The effectiveness of inquiry-based instruction in science: A comparative analysis. *Science Education*, *105*(2), 335–362.

Perplexity, A. (2025). *AI-powered research and writing assistant*. San Francisco, CA: Perplexity AI.

Rai, P. K., Sonne, C., & Kim, K.-H. (2023). Heavy metals and arsenic stress in food crops: Elucidating antioxidative defense mechanisms in hyperaccumulators for food security, agricultural sustainability, and human health. *Science of The Total Environment*, *874*, 162327.

Rawat, K. S., Elahi, M., & Kumar, B. (2023). *Education and training program to improve preparedness and increased access to energy workforce for engineering technology graduates*. Paper presented at the The 2023 ASEE Annual Conference & Exposition.

Robertson, W. H. (2014). *Action science: Relevant teaching and active learning*. Thousand Oaks, CA: Corwin Press.

Robertson, W. H. (2022). The constructivist flipped classroom. *Journal of College Science Teaching*, *52*(2), 17-22. https://doi.org/10.1080/0047231X.2022.12290644

Robertson, W. H., & Tillman, D. (2024). Action science: Teaching physics and engineering through extreme sports. *Journal of STEM Education*, *25*(1), 14–19.

Robertson, W. H., & Tillman, D. A. (2024). Creative action science using extreme sports. In (pp. 201–216). Cham, Switzerland: Springer International Publishing.

Seidel, T., & Stürmer, K. (2014). Modeling and measuring the structure of professional vision in preservice teachers. *American Educational Research Journal*, *51*(4), 739-771. https://doi.org/10.3102/0002831214531321

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review*, *57*(1), 1-23.

Society of Women Engineers. (2024). *Mobile labs offer a new path into STEM*. USA Chicago, IL: Society of Women Engineers.

Southard, K. M., Christen, J., & Gupta, A. (2024). Integrating learner-centered design and user-centered design for meaningful instructor onboarding: Supporting large-scale curricular changes to general education. *To Improve the Academy: A Journal of Educational Development*, *43*(2), 87–105.

Starobin, S. S., Schenk, T., & Laanan, F. S. (2018). Building better bridges into STEM: A synthesis of 25 years of STEM bridge programs. *CBE—Life Sciences Education*, *17*(1), es3.

Sweller, J., Ayres, P., & Kalyuga, S. (2024). *Cognitive load theory: Research and educational applications*. Cham, Switzerland: Springer.

Tammets, K., & Ley, T. (2023). Integrating AI tools in teacher professional learning: A conceptual model and illustrative case. *Frontiers in Artificial Intelligence, 6,* 1255089. https://doi.org/10.3389/frai.2023.1255089

Todd, W. F., Atchison, C. L., & White, L. D. (2023). Amplifying the voices of diverse scholars to integrate culture in the Earth sciences. *Journal of Geoscience Education, 71*(3), 281-287. https://doi.org/10.1080/10899995.2022.2140276

Wang, S., Christensen, C., Cui, W., Tong, R., Yarnall, L., Shear, L., & Feng, M. (2023). When adaptive learning is effective learning: Comparison of an adaptive learning system to teacher-led instruction. *Interactive Learning Environments, 31*(2), 793-803. https://doi.org/10.1080/10494820.2020.1808794

WISE. (2026). *Women in science and engineering (WISE).* Retrieved from https://www.wisecampaign.org.uk/

Yang, Y., Asselin, G., & Osgood, R. (2018). Professional development and perceived change in teaching practices. *Journal of Science Teacher Education, 29*(1), 46–63.

Yang, Y., Asselin, G., & Osgood, R. (2020). A systematic review of the effectiveness of professional development in improving student learning. *Journal of Science Teacher Education, 31*(4), 332–357.

Yoh, T., Kim, J., Chung, S., & Chung, W. (2021). STREAM: A new paradigm for STEM education. *Journal of STEM Education: Innovations and Research, 22*(1), 15–24.