Table. TPACK in the Course

Num	Course Name	Rationale & Essence for TPACK Categorization	Key TPACK Aspects Addressed
1	AI for Physics Learning	This course is the epitome of cutting-edge TPACK as artificial intelligence (AI) represents a disruptive technology that reshapes pedagogical paradigms, with its essence being the integration of AI as an intelligent tool and tutor to create personalized, adaptive, and interactive physics learning experiences unachievable through conventional methods, thereby directly synergizing Technological Knowledge (TK), Pedagogical Knowledge (PK), and Physics Content Knowledge (CK).	1. TK-CK Integration: Understanding how AI processes and represents physics content. 2. PK-TK Synergy: Designing teaching strategies that leverage AI's strengths (e.g., generative AI, adaptive learning). 3. Contextual Application: Applying AI solutions to real-world classroom physics problems.
2	Developmen t of Digital Learning Tools	This course is categorized under TPACK because modern learning requires interactive and self-directed media, with its essence focusing on design thinking and instructional design to create technological products (like simulations, apps, or e-modules) that are pedagogically effective and specifically tailored to teach particular physics concepts, demanding a precise balance between Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK).	1. Design Thinking: Designing with consideration for CK (physics misconceptions), PK (learning theories), and TK (development platforms). 2. TK-PK-CK Balance: Balancing all three components to ensure the product is not only technologically advanced but also pedagogically sound and scientifically accurate.
3	Multimedia for Physics Learning	The rationale for its TPACK categorization is that many physics concepts are abstract and require visualization, with its essence being the application of cognitive psychology principles (like the Cognitive Theory of Multimedia Learning) to select, combine, and design media elements (text, sound, images, video) to facilitate a deeper understanding of physics content, representing a direct integration of Technological Knowledge (TK) and Pedagogical Knowledge (PK) to deliver Content Knowledge (CK).	1. Cognitive Theory of Multimedia Learning: Applying principles like coherence, signaling, and segmenting in a physics context 2. TK-PK Integration: Choosing multimedia technology based on its pedagogical effectiveness for specific physics topics.

Num	Course Name	Rationale & Essence for TPACK Categorization	Key TPACK Aspects Addressed
4	Internet of Things in Physics Learning	This course belongs to TPACK because IoT brings real-world context and live physical data directly into the classroom, with its essence being the transformation of the surrounding environment into a "living laboratory" by using sensors and IoT devices to collect real-time data, thereby connecting pure physics concepts (CK) with practical applications through inquiry-based pedagogy (PK) mediated by advanced technology (TK).	1. Real-World Context: Connecting CK with tangible phenomena. 2. Inquiry-Based PK with TK: Designing discovery-based learning activities centered on IoT data. 3. Data Literacy: Integrating the skill of interpreting sensor data as part of CK.
5	Deep Learning Modeling	The rationale for TPACK categorization is that students' deep understanding of physics requires strategies beyond memorization, with its essence being the design of complex, contextual, and meaningful learning experiences—often aided by technology—to foster knowledge transfer and higher-order reasoning about physics concepts, thus blending sophisticated Pedagogical Knowledge (PK) with Content Knowledge (CK) and supporting Technological Knowledge (TK).	1. PK-CK Fusion: Designing performance tasks and projects that demand deep application of CK. 2. Technology as a Cognitive Partner: Using TK (e.g., modeling software) to support complex student thinking.
6	Science Lab Management for Sustainable Learning	This course is categorized under TPACK with the rationale that the laboratory is the heart of inquiry-based science pedagogy, where its essence is to manage and utilize all laboratory technologies (from simple to advanced devices) effectively and safely to support inquiry-based and problem-solving pedagogy in learning science content and sustainability issues (ESD), thus demanding a practical integration of Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK).	1. TK in Practical Context: Managing lab technology to support PK. 2. Inquiry-Based PK: Designing authentic lab activities. 3. CK for ESD: Integrating sustainability content into lab practice.

Num	Course Name	Rationale & Essence for TPACK Categorization	Key TPACK Aspects Addressed
7	STEM-ESD Education	TPACK categorization is based on the rationale that real-world challenges are interdisciplinary and require the integration of Science, Technology, Engineering, and Mathematics, with its essence being the application of project-based learning and problem-solving pedagogies that naturally integrate Technology (TK) and Engineering to study Physics Content Knowledge (CK) within the context of sustainability (ESD), representing the pinnacle of TPACK integration.	1. Integrative Pedagogy (PK): Teaching approaches that unify multiple disciplines. 2. Technology & Engineering as Context (TK & CK): Positioning technology and engineering as tools and contexts for learning science. 3. Authentic Assessment: Assessing students' integrative abilities.
8	Adaptive Assessment for Inclusive Classrooms	This course is part of TPACK because every student has a unique way of demonstrating understanding, with its essence being the design and implementation of assessment techniques and tools (both digital and non-digital) that can adapt to the individual needs of students in inclusive classrooms to accurately measure their mastery of physics content, thereby combining Pedagogical Knowledge (PK) about differentiation, Technological Knowledge (TK) for personalization, and Physics Content Knowledge (CK).	1. Specific PK-CK: Understanding how to assess physics understanding in diverse learners. 2. TK for Differentiation: Leveraging technology to create and manage personalized assessments. 3. Equity & Access: Ensuring assessments are fair for all.

Num	Course Name	Rationale & Essence for TPACK Categorization	Key TPACK Aspects Addressed
9	Data Science for Physics Learning	The rationale for TPACK categorization is that pedagogical decision-making should be based on data, not intuition alone, where its essence is using data science methodologies and technological tools (TK) to analyze learning data (e.g., assessment results, interaction logs) to gain insights into student learning processes and teaching effectiveness, thereby enabling evidence-based improvement of pedagogical practices (PK) for physics content (CK).	1. Assessment Literacy (PK-CK): The ability to assess physics understanding. 2. Learning Analytics (TK-PK): Translating data into pedagogical strategies. 3. Data-Informed Instruction: The cycle of teaching improvement based on data.
10	School Physics	This course is the core of TPACK with the rationale that a gap exists between physics as an academic discipline and the knowledge that must be taught in schools, where its essence is to analyze, select, and transform complex Physics Content Knowledge (CK) into forms that are comprehensible, engaging, and meaningful for students by using appropriate pedagogical strategies (PK) and leveraging technology (TK) for visualization and experimentation, representing the practice of technology-enriched Pedagogical Content Knowledge (PCK).	1. Core PCK: The transformation of CK for teaching purposes. 2. Concept Representation: Using analogies, demonstrations, and technology to visualize abstract concepts. 3. Anticipating Misconceptions: Understanding specific learning difficulties for particular physics topics.