**Glossary of Terms**

**Adaptation level of interactivity:** interactive learning environments that involve responses that are tailored to the learner previous behavior, even though they are selected from a fixed pool of options. Adaptive interactive learning environments dynamically tailor the real-time selection of learning tasks, instructional procedures and formats based on the information about learner current and past actions and online behavior.

**Adaptive expertise:** ability of experts to flexibly approach new situations by changing available or creating new procedures when the known approaches do not work in new situations. Developing adaptive expertise requires combining higher level general knowledge structures, practice in carrying out basic procedures in specific contexts, and variation in practice contexts for the development of flexible skills.

**Adaptive guidance strategy:** an advisement strategy that provides learners with diagnostic information about the current level of knowledge, advise on what to study or practice to achieve mastery, how to sequences learning tasks for gradual transition from basic to more complex strategies, and how to allocate cognitive resources. As learners acquire basic knowledge, adaptive guidance tailors subsequent more advanced learning tasks.

**Adaptive hypermedia learning environments:** hypermedia environments that accommodate learner characteristics into an explicit learner model and use this model to adapt interactions with each learner to her or his characteristics and needs, for example, by providing adaptive content selection, presentation formats, or suggesting a set of most relevant links to proceed.
Adaptive instructional systems: learning environments that react dynamically to learner needs and their individual characteristics (such as prior knowledge, preferences, learning goals, learning styles, and cognitive abilities), for example, by presenting suitable information, learning materials, and instructional support.

Advisement strategy: a form of instructional assistance provided to learners for making their own learning decisions that combines a degree of learner control with the system-controlled evidence-based task selection.

Animated pedagogical agents: onscreen characters (not necessarily human-like) that provide guidance and necessary feedback using various forms of communication (verbal explanations, gazing, gesturing, etc.). Pedagogical agents may also effectively motivate learners.

Aptitude-treatment interactions (ATIs): interactions that occur when different instructional treatments result in differential learning rates depending on student aptitudes. The aptitude is broadly understood as any learner characteristic that influences results of a particular educational treatment. Relevant aptitudes include knowledge, skills, learning styles, personality characteristics, etc. Learner prior knowledge is the aptitude of interest in the context of the expertise reversal effect.

Assistance dilemma: balancing the executive guidance between knowledge-based and instruction-provided guidance. Within a cognitive load framework, the explanatory feedback is capable of providing external instructional guidance in place of missing internal long-term memory structures.

Automatic cognitive operations: cognitive processes that require minimal resources and do not interfere with other cognitive operations, in contrast to controlled or effortful processes that require considerable attentional capacity. Automatic operations allow to encode some elements of information directly and automatically into long-term memory without conscious effortful processing in working memory.

Cognitive architecture: a general cognitive system that underlies human performance and learning. The understanding of human cognition within a cognitive architecture requires knowledge of corresponding models of memory organization, forms of knowledge representation, mechanisms of problem solving, and the nature of human expertise.
Cognitive load: the demand for working memory resources required for achieving goals of specific cognitive activities. This is a theoretical concept reflecting resources required for information processing in specific situations by a specific person when the individual is fully committed to the task. An actual amount of resources invested in a cognitive activity depends on many factors, including levels of motivation, attitudes, and other personality characteristics.

Cognitive load theory: an instructional theory describing instructional implications of processing limitations of human cognitive architecture (capacity and duration of working memory) and evolved mechanisms for dealing with these limitations (long-term memory knowledge base and its role in cognition). Cognitive load theory distinguishes between the essential (intrinsic and germane) and wasteful (extraneous) forms of cognitive load, and suggests a variety of techniques and procedures (cognitive load effects) for managing essential and reducing extraneous load in learning.

Cognitive modelling: observing skillful expert performance of complex cognitive tasks to construct an appropriate mental representation that would later guide learner cognitive activities and enhance learning outcomes. Such learning usually shows both what and why certain steps need to be done, and results in constructing more generalized schemas that could be applied in a wider range of situations. Cognitive modeling can place a heavy cognitive load on novice learners when the observed task performance requires examination from several perspectives.

Communication level of interactivity: dynamic interactive learning environments that involve flexible, non-predetermined responses to learners live queries that may be refined in an iterative process. This level may include features of the previous levels, for example, dynamic feedback, manipulation, real-time personalized task selection and information tailoring. Examples of this level of interactivity are online prompting for and submitting self-explanations or predictions for next procedural steps.

Completion assignments: means for implementing a completion strategy as a gradual transition from worked examples to unsupported problem solving practice. A completion assignment contains a problem statement, incomplete worked out solution, and tasks to complete. It provides a partially worked out solution procedure and asks learners to complete the solution.
Concurrent verbal reports (think-aloud protocols): the method for studying cognitive processes that could also be applied for evaluating cognitive load (with audio and video tracking of participants’ verbalizations and on-screen actions) by using the generated qualitative verbal data that reflects cognitive load caused by different types of sources and expressed through the participants’ own language. Verbal data from think-aloud interviews is coded using rubrics based on expected verbal expressions or remarks for different types of cognitive load.

Congruence principle: design principle for complex graphic according to which the content and format of the graphic should correspond to the content and format of the concepts to be conveyed. For example, animated graphics should be effective to represent change over time.

Dual-modality (audiovisual) presentations: presenting textual information in an auditory form with pictures or diagrams in a visual modality that effectively increases working memory capacity by using combined resources of the visual and auditory channels of sensory and working memory that may exceed the processing capacity of a single channel. Dual mode presentations may be used to reduce extraneous cognitive load caused by split-attention.

Dual-task technique: measures of cognitive load that use performance on simple secondary tasks as indicators of cognitive load associated with performance on main tasks. Various simple responses are used as secondary tasks, for example, reaction times to some events, counting backwards, recalling the previous letter seen on the screen of a separate computer while encoding the new letter appearing after a tone sounded.

Dynamic adaptation: instructional adaptation approach based on continuous tracking of learner activities. Dynamic adaptation belongs to system-centered forms of adaptation that are contrasted with the learner-centered adaptation that provides learners with possibilities to select available options themselves.

Executive function in learning: cognitive function associated with the engagement and coordination of different cognitive activities and directing learner attention to appropriate information. Within the cognitive architecture based on interacting working memory and long-term memory, the executive function during complex cognitive processing is provided by available domain-specific schematic knowledge base in long-term memory.
**Expertise**: superior levels of professional accomplishments in a field that require many years of training and extensive deliberate practice at a challenging level of difficulty. Professional expert performance requires well-developed cognitive skills, well-organized high-level knowledge structures, and self-regulatory performance control or metacognitive strategies.

**Expertise reversal effect**: reversal in the relative effectiveness of information presentation formats and procedures as levels of user knowledge in a domain change. For example, extensive external support could be beneficial for novices when compared with the performance of novices who receive a low-support format, but is disadvantageous for more expert users when compared with the performance of experts who receive a low-support format.

**Extraneous cognitive load**: non-essential for learning cognitive load that is associated with a diversion of cognitive resources on activities irrelevant to performance and learning. It is imposed by the design of learning tasks and information presentations (e.g., separated in space and/or time related elements; an excessive step-size or rate of introducing new elements of information; insufficient instructional support that cannot compensate limited learner knowledge base; excessive externally provided guidance that overlaps with user knowledge base).

**Faded worked-out examples**: an instructional method that implements the principle of scaffolding by gradually fading worked-out steps in the examples (and replacing them with corresponding problem solving steps) with increased levels of learner expertise.

**Faded worked examples**: an instructional method for the gradual transition from worked examples to problem solving practice. Parts of worked examples are progressively replaced with problem-solving steps for learners to complete. Worked examples are gradually faded as levels of learner task-specific expertise increase, thus implementing the principle of scaffolding.

**Feedback level of interactivity**: interactive learning environments that provide a pre-defined feedback on specific learners’ actions. The feedback could be immediate or delayed; simple, corrective or extended explanatory; with or without a learner control.
**First-step diagnostic method**: a method that realizes the rapid diagnostic assessment approach by presenting learners with selected tasks for a limited time and asking them to rapidly indicate their first step toward solution of each task. The first step would involve different cognitive operations for individuals with different levels of expertise in a specific task domain. For more experienced learners, their well learned higher-level solution procedures would allow these learners to rapidly generate advance steps of the solution skipping some intermediate steps.

**Four-component instructional design model (4C/ID)**: instructional design model that provides methods for analysis of complex cognitive skills, knowledge structures required for performing these skills, and development of appropriate sequences of whole task practice situations that would support acquisition of these skills. The model includes four interconnected components: learning tasks, supportive information, just-in-time (algorithmic) information, and part-task practice.

**General-to-specific task analysis**: an approach to cognitive task analysis that requires identifying the main idea of a task followed by determining the specific aspects of this idea (broader concepts are consequently differentiated into more specific ones).

**Germaine cognitive load**: learning-relevant demands on working memory traditionally associated with various auxiliary cognitive activities (e.g., explicit self-explanations during learning from worked examples or imagining procedures described in instructional materials) that are intentionally designed with the purpose of fostering learning, enhancing learning outcomes, or increasing levels of learner motivation.

**Hypermedia learning environments**: learning environments that add navigation support to traditional linear multimedia environments, thus providing appropriate levels of learner interactivity and learner control. They are usually implemented as an organized network of hyperlinks that allow learners nonlinear access to graphics, sound, animation, and other multimedia elements.

**Iconic representations**: representational formats for input parameters used in instructional simulations that contain (in addition to traditional symbolic verbal and numerical) concrete, “situated” graphics to represent the various elements of the physical environment (e.g. flames to represent temperature, weights to represent pressure, etc.). Adding iconic representations may enhance instructional effectiveness of simulations, especially for novice learners.
**Imagining technique:** imagining procedures and concepts rather than repeatedly studying the examples and explanations in order to increase germane cognitive load. The imagining technique is beneficial for more knowledgeable learners. It could be used to replace worked examples when instructing relatively more experienced learners.

**Instructional efficiency:** an approach to evaluating learning outcomes that considers learning and instruction in terms of cognitive cost (cognitive resources spent, mental effort invested, or cognitive load imposed) of achieving instructional effects rather than their mere effectiveness. According to this approach, the whole point of investing considerable human and financial resources into the design and development of sophisticated interactive multimedia learning environments is to achieve returns in terms of efficiency: learning faster and without mental stress.

**Intelligent tutoring systems:** learning and assessment environments based on complex problem solving in which selecting and sequencing of learning tasks occur as a function of learner responses to complex tasks based on a model of learner knowledge. Intelligent tutoring incorporates individualized instruction using detailed assessment of learner knowledge and appropriately directing instructional treatments. Intelligent tutoring systems based on the model-tracing methodology simulate student cognition in real time and maintain current models of student knowledge state. The learner actual performance is traced and compared to the ideal solution structure using a production rules model, and the student is kept on the correct solution path.

**Intrinsic cognitive load:** cognitive load caused by levels of interactivity between elements of information that need to be processed simultaneously (relative to levels of learner expertise). It is associated with cognitive activities of establishing connections between related elements of information in working memory and integrating them with available knowledge base in accordance with specific instructional goals. These cognitive activities essentially signify comprehension of the situation and may result in modified or new knowledge structures in long-term memory.

**Learner-controlled approach to individualization of instruction:** an adaptive approach according to which learners are enabled to adapt the learning environment by actively and continuously selecting treatments most appropriate to their cognitive states. It is an alternative way of dynamic tailoring of instruction to learner cognitive characteristics.
Learner (student, user) models: key component of an adaptive hypermedia system that includes many different user characteristics (e.g., level of computer literacy, experience in using specific software applications, learning styles, background, preferences, goals, interests, etc) in addition to subject matter knowledge. Learner models are usually constructed by using testing and survey methods, or recording the history of user interactions with the system.

Long-term memory (LTM): a major part of our cognitive architecture, an organized knowledge base that stores massive amount of hierarchical knowledge structures.

Long-term working memory (LTWM): cognitive construct created by knowledge structures in long-term memory associated with active components of working memory. It is capable of holding virtually unlimited amount of information due to the chunking effect. For example, when reading a text, we construct and continuously update in working memory a situation model of the text using our knowledge base long-term memory. This situation model represents the current content of long-term working memory. Due to the association with a stable long-term memory knowledge base, this content is sufficiently stable, durable, and resistant to temporary interferences (e.g. interruptions in reading).

Manipulation level of interactivity: interactive learning environments that involve real-time online change or transformation of information in response to learners’ actions; provide flexible, variable responses, although not tailored to the learner previous behavior. This level of interactivity may involve different degrees of learner control.

Measures of instructional efficiency: indicators of the relative efficiency of instructional conditions and the cognitive cost of learning generated by different ways of combining measures of performance with measures of cognitive load. High efficiency learning generally occurs under conditions of low cognitive load and high test performance, and low efficiency occurs under high cognitive load and low test performance.

Measures of instructional involvement: indicators of the relative levels of learner motivation in instructional conditions generated by combining measures of performance with measures of mental effort. The measure of motivation should take into account not only the invested mental effort but also the associated performance data. When learner involvement is higher, more mental effort is likely to be invested that would result in higher performance.
**Micro-treatment adaptation approach:** adaptation approach based on fine-grained within-task measures taken while students are in the instructional situation with varying amount of prompting, feedback, and examples. This approach is used together with macro-treatment approach (pre-task adaptation model) by selecting macro-treatments based on initial pre-task measures, and then refining and optimizing instructional procedures based on continuous monitoring of learning behavior.

**Modality effect:** an instructional effect according to which presenting one of the essential and related sources of information in an auditory form, thus engaging another processing channel in working memory and effectively expanding its available capacity, may reduce or eliminate split attention and facilitate learning. The amount of information that can be simultaneously processed using both auditory and visual channels might exceed the amount of information processed in a single channel. Therefore, instructional materials that present information using dual- or multiple modalities (for example, a visual diagram accompanied by an auditory text) can be more efficient than equivalent single modality formats.

**Multimedia redundancy effect:** an instructional effect according to which duplicating textual explanations using different modalities may inhibit learning. When auditory textual explanations of a diagram are presented concurrently with the same on-screen text, learners need to mentally relate corresponding visual and auditory components of instruction. Processing on-screen textual explanations of a diagram together with the same auditory explanations imposes an additional cognitive load. Elimination of a redundant source of information may enhance learning in this situation.

**Optimization of cognitive load:** the process of using essential instructional guidance and removing redundant components as the level of learner task-specific expertise gradually increases, thus reducing extraneous and enhancing essential cognitive load. Such optimization assumes not only presenting appropriate information and instructional guidance at the appropriate time, but also timely removal of unnecessary redundant information as learner levels of learner expertise increase.

**Pre-task adaptation model:** instructional adaptation approach according to which instructional treatments are determined from aptitude measurements taken before the actual learning situation, and then assigning certain types of students to specific instructional treatments.
Principle of scaffolding: an instructional design principle implementing the general adaptive approach to tailoring levels of instructional guidance to levels of learner expertise. The principle suggests using worked examples, completion assignments, and conventional problems combined in a completion strategy.

Process-oriented worked examples: worked examples that focus on expert reasoning behind performance steps and the corresponding cause-effect relationships.

Product-oriented worked examples: worked examples that focus mostly on demonstrating procedural steps required for achieving specific results (or products).

Rapid diagnostic approach: diagnostic assessment of expertise based on rapidly determining if and how learners use their knowledge structures while approaching a specific problem or situation. The idea of the approach is to determine the highest level of organized knowledge structures a learner applies rapidly to a task or situation. More experienced learners would immediately see the task within their higher-level knowledge structures. Novices may only be able to identify some random lower-level components. Organized knowledge base in long-term memory is the main factor determining such differences.

Rapid verification diagnostic method: an alternative method that realizes the rapid diagnostic assessment approach by presenting learners with a series of potentially possible steps at various stages of the solution procedure, and asking them to rapidly verify the correctness of these steps instead of generating the steps themselves. This method is easier to implement in online learning environments, and it is also usable for relatively poorly defined tasks when solution steps could not be specified exactly in advance.

Redundancy effect: an instructional effect according to which elimination rather than integration of redundant sources of information could produce better learning outcomes in situations when individual sources of information could be understood separately (e.g., self-explanatory diagrams or textual explanations). If a source of information is fully intelligible on its own, then any additional redundant sources of information should be removed from the instructional materials rather than integrated into it.

Retroactive inhibition: interference between new and earlier information in animations when the following frame in the animation needs to be processed before the information from previous frames has been incorporated into an organized knowledge structure and comprehended.
**Segmentation effect:** an instructional effect according to which concurrent presentation of the same audio and visual text by small portions (instead of one large uninterrupted chunk) may improve learning outcomes. The size of textual segments that are processed continuously without a break may influence the conditions of applicability of the multimedia redundancy effect.

**Self-explanation technique:** prompting learners for self-explanations and predictions. It requires explaining explicitly suggested solution steps or actions based on learned principles of the domain or predicting the next procedural step before demonstrating or describing this step. The technique could be used to increase germane cognitive load.

**Shared instructional control model:** an approach to personalized task selection according to which the system selects a subset of tasks from an available task pool based on the current level of learner expertise, and then the learner makes the final task selection. As the learner proceeds through the training session, the system continuously assesses performance and invested mental effort and selects an optimal subset of tasks for the following learning step. This subset is presented to the learner who makes the final selection. The model combines a system-controlled task selection based on learner levels of expertise and a learner-controlled task selection.

**Signaling or cueing effect:** an instructional effect according to which providing cues to the learner on what to pay attention to or how to select and organize the material (e.g., by placing arrows, using flashing or highlights to attract learner attention to a particular components of animation) may enhance learning. Visual cues could help learners connect the corresponding verbal and pictorial elements of information, reduce cognitive resources for co-referencing these sources of information, and improve learning outcomes.

**Sources of cognitive load:** features of external information structures and/or cognitive characteristics of individual users that determine required working memory resources.

**Split-attention effect:** an instructional effect according to which physically integrating different essential sources of information (e.g., textual explanations located near its matching parts on a picture) significantly improves learning performance. If neither explanations nor pictures can be understood separately, the statements in the explanatory text need to be mentally coordinated with corresponding elements in a picture. Such mental coordination processes require additional cognitive resources that are not directly related to learning. Similar problems could occur
in temporal split-attention situations when corresponding words and pictures are presented successively rather than simultaneously.

**Subjective ratings of cognitive load:** measures of cognitive load that are based on the assumption that people are able to introspect their conscious cognitive processes. Ratings of subjective mental effort associated with learning instructional materials have been used in most of studies in cognitive load framework as they are easy to implement, do not intrude on primary task performance, are sufficiently reliable, and correlate highly with objective measures.

**Task-specific expertise:** ability of a person to perform fluently in a specific class of tasks. It is a “narrow” definition of expertise in contrast to expertise in a professional domain. The availability of highly organized and automated domain-specific knowledge base is a common characteristic of both task-specific and broader professional expertise. The importance of task-specific expertise is in freeing cognitive resources required for learning higher-level tasks and developing flexible and transferable skills by acquiring well automated knowledge structures and procedures.

**Transient nature of animations:** the need to hold in working memory elements of information from earlier frames of the animation while attending to the following frames. Cognitive demands of processing new information while holding previous information in active state in working memory could overburden working memory resulting in cognitive overload. In many situations, some essential components of the preceding frames could be lost before the related elements of the following frames appear.

**Worked examples effect:** an instructional effect according to which studying more worked examples (that provide all the appropriate solution steps for a problem) instead of solving equivalent conventional problems may lead to better learning outcomes (including transfer performance) achieved faster and with less wasteful cognitive load. While studying a worked example, learners attend simultaneously only to one problem state and an associated solution step. This process requires significantly less working memory capacity thus reducing extraneous cognitive load and facilitating learning.

**Working memory (WM):** a major part of our cognitive architecture, a functional mechanism that limits the scope of immediate changes to long-term memory. Depending on a specific model, working memory is considered either as a separate component of our cognitive system, or as an activated part of LTM. The essential
attribute of working memory is its severe limitations in capacity and duration when dealing with novel information.