Enhanced Learning Experience and Knowledge Transfer

Instructional Design and Didactic Guidelines: An Overview

Author(s)  Michael Kickmeier-Rust (UniGraz)  
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1. Learning – Cognitive Learning Theories

a. Knowledge Construction and Integration

- Cognitive learning theories as well as the constructivist approach to learning assume that learners do not “acquire” knowledge but rather interact with new information, interpret it, encode it, integrate it into existing knowledge, and thus build new personal knowledge. Information per se is not seen as knowledge but rather as a stimulus that evokes the construction of knowledge by cognitive processing.
- Constructivist approaches to learning do not view knowledge as information transmitted by a teacher but rather as the result of a learner’s active engagement in the process of comprehension and conception of information. A learner actively constructs new knowledge, as in cognitive theories, this construction occurs by assigning meaning to an information and by relating it to prior knowledge (Wittrock, 1974).
- The use of clues and structural information to facilitate the integration of new knowledge into a macrostructure of prior knowledge improves learning of explanatory knowledge (Mayer, 1979).

b. Learning Styles

- See also Schulmeister, 2004, pp. 19-23

c. Metacognition

- Strategic and met-cognitive think plays a crucial role in hypermedia learning (Foltz, 1996). As an example, learners have to continuously which learning objects of a range of given possibilities to address next and to evaluate to which extent chosen learning paths were successful in order to reach a given learning goal (Schnotz, 1998).
- In learning environments within which learners can select instructional material and , thus, be able to determine pace and sequence of learning, the importance of suitable meta-cognitive strategies increases. Experiments (e.g., Gerjets, Scheiter, & Tack, 2000) showed that learners have difficulties in selection the most important or the most profitable information in educational settings.

d. Other

- Chen (2002) investigated the impact of field dependent and field independent cognitive styles on learning in non-linear hypermedia environments. She concluded that open, non-linear learning environments are not suitable for all learners. Field dependent learners may need more support and guidance than field independent learners. [See Chen, 2002 for more details]
2. Adaptivity - Adaptability

a. Requirements

- What Reigeluth & Garfinkle (1994) recommended for teachers must also be accomplished by adaptive educational environments. They must be a “guide on the side than a sage on the stage” (Reigeluth & Garfinkle, 1994, p. 60). In terms of adaptive systems this means that they must provide guidance for learners in selecting appropriate instructional goals and, further on, they must assist learners in identifying and coordinating the most successful way to reach the goals.
- Reigeluth & Garfinkle (1994) are optimistic that “computer-based simulations will be excellent tools for […] maximizing active involvement and construction of learning” and that they represent valuable tools for assessing knowledge and skills.
- Customization, diversity, or holism (Reigeluth, 2005)
- Reigeluth (2005) stresses the problem of standardization in present education, by teacher and eLearning systems. Students are “treated as if they are all the same and are all expected to do the same things at the same time”. He requests that instructional strategies must allow learners to achieve deep understanding, causal dynamics, and meta-cognitive skills. Thus, these strategies must provide guidance in selecting appropriate goals, identifying appropriate entry points for learning, engaging in the topic, and these strategies must allow a continuous assessment of understanding.
- According to Reigeluth (2005), an important evolution towards new educational approaches is adaptive educational systems (in his words “personal tutors”). He emphasizes characteristics like adaptation to individual needs, interests, and learning styles. Further on, he recommends a continuous monitoring and improvement of instructional methods and a strict separation of instructional methods and content.

b. Pros and Cons

- See also meta-cognition for arguments for adaptive systems.
- According to Niederhauser, Reynolds, Salmen, & Skolmoski (2000), non-linear learning environments (e.g., hypertexts) cause extraneous cognitive load. Thus, reducing the amount of selection and sequencing efforts of students should significantly reduce cognitive load. On the other hand, this might neutralize the benefits of nonlinear learning environments (Schuh, Gerjets, & Scheiter, 2004), for example, the adaptation of learning sequences to individual needs.
- Schulmeister (2004) argues that the future of eLearning or technology-enhanced learning (TEL) should not be systems which adapt to a learner’s needs but which enables the learner to individualize learning according to its own ideas. Similar ideas come from Issing (1995) who argues that optimal learning might be provided by open learning environments which enable learners to autonomously organize learning. These authors, however, forgets that educators cannot expect a sufficiently
high level of meta-learning abilities and meta-cognitive skills in general from
learners; especially novices have likely troubles figuring out the appropriate
learning objects or sequences.
- Winn & Snyder (1996) argue for learning environments which are not “entirely
prescribed but which can adapt to students needs in real-time”.
- Hypermedia learning environments are often highly complex and large
environments. The freedom to navigate within hypermedia learning
environments, however, might reveal major disadvantages like a significant
increase of complexity and (extensive) cognitive load (cf. Chen, 2002).

c. Cognitive Models

- Successful adaptive education systems require cognitive models. According to
Rittle-Johnson & Koedinger (2001), cognitive models have four major
advantages: (a) cognitive models incorporate precise and unambiguous
specifications, (b) they allow formulating specific hypotheses, (c) they help to
explain empirical results, and (c) they provide concrete guidelines for
instructional design.
- ACT-R breaks down knowledge into two main categories, declarative and
procedural knowledge. Moreover, the model includes precise production rules,
simple if-then statements, which allow modelling actions for problem solving

d. Learning Paths / Branching

- Traditional eLearning systems are rather linear, presenting learning objects one
after the other and thus do not support the associative nature of the human
mind (Khalifa, 1998). Today, a linear sequence of presenting contents is seen
as an inadequate approach to tutorial design.
- Khalifa (1998) demonstrated that a non-linear hypertext structure could
improve learning of structural knowledge in comparison to linear text.
- Gikas & Van Eck (2004) differentiated linear gaming and learning experience
and learner controlled sequences. The latter one denotes personalized learning
paths.

3. Game-Based Learning

a. Requirements for better learning

- Learning environments should be authentic, based on real-world problems, and
rich for learning (Reigeluth & Garfinkle, 1994). Learning objects should
address specific knowledge and general skills such as transfer, negotiation,
interpersonal skills, or decision-making skills (Reigeluth & Garfinkle, 1994).

b. Pros (Learning Theories)
• Computer games potentially support the construction of knowledge because they are able to provide an immersive, intrinsically logical environment within which new information can be perceived and integrated into a meaningful whole. New and unusual perspectives may facilitate the extension of existing knowledge and as the storyline of the game progresses, information may continuously converge to a comprehensive view of a domain of knowledge. As a key feature, playing a game requires the learner to actively be engaged in the game and thus actively be engaged in the construction process of knowledge. Information are not passively perceived but actively compiled. This persistent activity of the learner, being challenged by the game (e.g., moving the character through a virtual environment) and its educational contents (e.g., solving puzzles) significantly differentiates digital game-based learning from transmission and perception of traditional classroom teaching. Finally, games have the potential to present information in a meaningful context and to give information themselves an important meaning for the progress in the game. According to Wittrock (1974) exactly this feature is highly important for learning performance from a cognitive and constructivist perspective.

• Multi-user games enable collaborative construction of knowledge and interactions.

• Interactivity: Schulmeister (2004) emphasizes the importance of interactivity for learning. He argues that interactivity with learning objects is the focal point of eLearning which melds technological aspects and psycho-pedagogical aspects into a complete didactic solution. Interactivity means not a collaborative or social sense but it refers to the “manipulation and learning discourse with learning objects in the virtual space” (Schulmeister, 2004, p. 10). Also Lorenzo & Moore (2002) emphasize the importance of interactivity for effective eLearning.

• Tergan (2002) identified four types of contexts which significantly impact the success of learning: (a) individual context (prior knowledge, computer literacy, learning styles and strategies, or personality variables), (b) application context (authenticity, type of learning content, representation of learning content), (c) pedagogical context (instructional design, didactic preparation of learning content), and (d) technological context (design of learning content, navigation, accessibility, usability).

• Strzebkowski (1995) identified two types of interactions with learning environments, control activities (e.g., navigation) and didactic interactions (e.g., manipulating learning objects). For the latter he distinguishes two parameters which determine the level of interaction: the manipulation of the representation of the learning content and the manipulation and construction of content.

• A decisive factor of successful interaction is feedback. Keller (1983) identified three types of feedback, verbal approval and informative feedback, motivating feedback, and correcting feedback. According to Schulmeister (2004), these three types can be refined into: (a) feedback regarding navigation and orientation in the learning environment, (b) feedback regarding learning organisation and learning activities, (c) feedback regarding methodology, (d) feedback regarding learning contents, (e) feedback regarding motivation and motivational problems, and (f) feedback regarding psycho-social aspects of learning.

• Adaptivity is an important factor in virtual (3D) environments. Chittaro & Ranon (2000. 2002) attempted to use adaptive presentation technology for
dynamic generation of virtual worlds. According to Brusilovski (2004) adaptive approaches to virtual environments “can help the user to work more efficiently and avoid common problems such as navigation in the wrong direction, overlooking and important part of the space, and being lost”.

c. Pros (General)

- Gee (2003) argues that games might be “better sites” for preparing for the workplace than traditional schools.

d. Pros (Motivation)

- Randel, Morris, Wetzel, & Whitehill (1992) pointed out that computer games have the potential to support learners who motivation to learn. According to these authors review, best results can be achieved in domains like physics, maths, and language learning.

4. Pedagogy / Instructional Design

a. 8LEM

- The Eight Learning Events Model (8LEM) is a pedagogical approach which emphasizes that learning events are based on eight basic components. According to Leclercqce & Poumay (2005) on the basis of these eight components any number of training strategies can be deduced or, the other way round, any didactic strategy can be traced on these basic components. An advantage of the 8LEM approach is that unlike methods and strategies learning events can refer to intentional learning as well as incidental learning. The eight learning events are:
  - Imitation / Modeling: Describes incidental or intentional learning through observation and subsequent imitation. The role of a tutor or teacher is being a (role) model.
  - Reception / Transmission: Describes learning be receiving information or advice. The tutor’s role is transmitting information or advice.
  - Exercising / Guidance: Describes a “proceduralizing” and automation of skills. The tutor’s role is giving learners guidance and corrections.
  - Exploration / Documentation: Describes learning by a free investigation of information with a certain degree of freedom. The tutor’s role is to provide guidance, sources, or access.
  - Experimentation / Reactivity: Describes learning through manipulations of environments and observations of effects. The tutor’s role is to provide an “experimentable” and manipulable environment, i.e. providing reactivity.
  - Creation / Confrontation: Describes learning by creating now content or objects (e.g., texts, music, objects). Creation also includes a
reincorporation of know content. The tutor’s role is to foster creation process or confront learners with tasks of creation.

- **Self-reflection / Co-reflection**: Describes learning by reflecting the own knowledge and skills and the own learning processes. The tutor’s role is to guide learners in reflection processes.

- **Debate / Animation**: Describes learning by social interactions such as debates, arguments, and exchange of ideas. The tutor’s role is to “animate” and incite debates and discussions.

The advantages of this model are that it is observable; its components can be identified quantitatively and qualitatively. Moreover, the model is not deterministic; in specific situations more than one learning event can be present. For example, watching TV might include imitation of seen activities combined with perceiving information, or from the tutor’s perspective modeling and transmission.

The 8LEM allows describing existing learning or teaching strategies or programs. Moreover, from a prescriptive perspective, the model allows to plan and track learning or teaching activities. On this basis, 8LEM allows to assure a diversification of learning or teaching methods. Diversification of methods is a well-established pedagogical principle. Diversification of methods means to provide learners with a broader range of learning and teaching methods during the learning progress, instead of using continuously the same strategy (e.g., transmission). This approach is desirable from the perspective of individual skill development and also from the perspective of motivation. It is in the learner’s intrinsic interest to gain exposure to a broad range of learning modes. The learner’s "learning polyvalence" can be answered by the teacher’s "pedagogical polyvalence" as he orchestrates diverse experiences. The framework of 8LEM allows to plan learning and teaching on a very detailed basis. Furthermore, from a descriptive perspective it allows to assure a diversification of methods in order to empower learning and retain motivation.

### b. Bloom Taxonomy

- **Based on the initial question, how well people understand or know a subject**, Benjamin Bloom and colleagues (Bloom, 1956; Krathwohl, Bloom, & Bertram, 1973) identified three general types of learning: (a) the cognitive domain which includes skills and knowledge, (b) the affective domain which includes a development or growth in emotional areas and attitudes, and (c) the psychomotor domain which includes manual and physical skills. For each domain Bloom and his colleagues identified categories for the depth of learning.

The cognitive domain involves knowledge and the development of intellectual skills. This includes the recall or recognition of specific facts, procedural patterns, and concepts that serve in the development of intellectual abilities and skills. There are six major categories, which are listed in order below, starting from the simplest behavior to the most complex. The categories can be thought of as degrees of difficulties (Clark, 1999) which establish a hierarchical order. A more simple depth of knowledge or ability must be given in order to reach a deeper one. The categories are:

- **Knowledge**: The recall of factual information.
Comprehension: Understanding of the meaning, translation, interpolation, and interpretation of instructions and problems.

Application: Using of a concept in a new situation or unprompted use of an abstraction.

Analysis: Separating material or concepts into sub-components so that its organizational structure may be understood.

Synthesis: Building a structure or pattern from diverse elements. Joining parts to form a whole, with emphasis on creating a new meaning or structure.

Evaluation: Making of judgments about the value of ideas or materials. Additionally, so-called action verbs are assigned to each category, describing recall methods or abilities more detailed. For the category “knowledge” action verbs are, for example, define, describe, or label; for the category “analysis” compare, quantify, or measure.

Anderson & Krathwohl (2001) revised Bloom’s original taxonomy. These authors combined both the cognitive process and knowledge dimensions. This new expanded taxonomy can help instructional designers and teachers to write and revise learning objectives. The knowledge dimension includes factual knowledge, conceptual knowledge, procedural knowledge, and meta-cognitive knowledge, the cognitive process dimension includes the abilities remember, understand, apply, analyze, evaluate, and create. Thus, learning and teaching activities can be related to one of the 24 (4x6) combinations. Using the categories and the related action verbs, Bloom’s taxonomy allows precisely describing and planning learning objectives (e.g., a learner shall be able to apply knowledge about algebra to solve an equation”) and the design of knowledge assessments.

5. Didactic Strategies

a. General

- There are several ways for educators to plan lessons and courses. Most often teachers employ the principle of knowledge transmission (Leclerc & Poumay, 2005; Vermunt & Verloop, 1999). Accordingly, the same teachers use the same principle or educational strategy when they are asked to create eLearning courses. As a result of the linear sequencing of contents, demands arise for modern eLearning:
  - The need for a more personalized and adaptive approach to eLearning
  - The need for collaboration
  - The need for knowledge creation
  - The need to increasingly focus on teaching complex skills instead of transferring chunks of factual information (Van Merrienboer, 1997)
  - An increased focus on lifelong learning

- The work of Gagné (1965) is considered to be the origin of modern instructional design theories. In contrast to traditional learning theories, which are supposed to be descriptive, instructional design theories is supposed to be prescriptive, offering guidelines for educational work (Schulmeister, 2004).

- Some authors argued that instructional design theories could not reach a certain spread and application in education (e.g., Dick, 1991; Schulmeister, 2004; VanLehn, 1992). According to Issing (1995) a major question is whether
instructional design theories are at all able to provide problem-oriented learning in real learning contexts for a large number of learners.

- Andrews & Goodson (1980) compared 40 instruction models from the nineteen seventies.

### b. Example-based Learning

- Undoubtedly, examples are crucially important for educational goals. There are roughly two types of examples, worked examples and unsolved training problems. Sweller, van Merrienboer, & Pass (1998) found some evidence, that learning from worked examples is more efficient than learning from training problems. Conversely, a number of authors found significant disadvantages. Catrambone & Holyoak (1990) and VanLehn & Jones (1993) found that less successful learners have difficulties in reflecting the appropriateness of examples for other problems and in generalizing these examples. Ross (1989) found that learners might have difficulties to extract the main ideas of examples and that superficial features of examples often distract learners. Finally, Renkl (1999) argued that worked examples likely produce an *illusion of understanding*.

- Atkinson, Derry, Renkl, & Wortham (2001) identified instructional principles and processing strategies. For example, a successful principle might be the provision of multiple examples with different superficial features or the provision of completion problems within which certain information of worked examples must be added. However, Gerjets, Scheiter, & Tack, (2000) found in an experiment that most students did not consider more than one example in the learning process.

### c. Problem-based learning

- See Merrill (2002); see d) First Principles
- It’s a common opinion in instructional research that engaging students in solving problems fosters learning (Merrill, 2002). The approach of problem-based learning is an integral part of many instructional models like Cognitive Apprenticeship (Collins, Brown, & Newman, 1989), Constructivist Learning Environments (Jonassen, 1999), Problem-based Learning (Savery & Duffey, 1995), or Novel Problem Solving (Clark & Blake, 1997).

- According to Merrill (2002) problem-based learning involves four primary levels of instructions:
  - **Activation**
    In case that learners do have prior knowledge or experiences regarding a certain topic, this knowledge must be activated in order to have a foundation for new knowledge. In case that learners do not have such prior knowledge a “three-dimensional” experience should be provided, which can be used by learners as a foundation. Andre (1997) emphasizes the role of advance organizers (Ausubel, 1960) for the (schema) activation process and stresses related problems.
  - **Demonstration**
    A fundamental principle of instruction is to provide learners with mental models that allow the solving of novel problems. Thus, learning
can be facilitated by providing students with examples instead of transmitting “generalities”. Thus, examples for problems must be demonstrated (Merrill, 2000). Dijkstra & van Merrienboer (1997) identified three classes of problems: (a) categorization, (b) plans and procedures, and (c) interpretation. Successful learning requires providing demonstration and thus mental models of all three types of problems. Moreover, a number of authors (e.g., Gentner & Namy, 1999 or Schwartz et al., 1999) emphasize the importance of different perspectives and multiple representations of problems.

**d. Models**

- **First Principles (Merrill, 2002)**
  On the basis of previous research and existing models, he identified so-called first principles of instruction. The term “first principles” equals Reigeluth’s (1999) term “basic methods”. These principles are primarily based on the idea of problem-based learning, which is considered to be a very effective approach to learning. The principles are: (a) Relying on real-world problems, (b) activation of prior knowledge, (c) new knowledge must be demonstrated to the learner, (d) learners shall apply the new knowledge, and (e) the new knowledge must be integrated into the “the learner’s world”.
    
  - Application
    
    New knowledge must be applied to relevant problems. Practise therefore must be consistent with the learning goal (Gagné, 1965, 1985). During the application phase errors are a natural outcome. Learning is facilitated when learners are provided with possibilities to recognize errors and how to recover from errors.
    
  - Integration
    
    Integrating new knowledge into existing knowledge and skills is a fundamental premise of successful and durable learning. “Knowledge is soon forgotten if it is not made a part of the learner’s life beyond instruction” (Merrill, 2002).

A large part of existing models and theories of instructional design and strategies include the first principles of instruction.

- **Star Legacy of Vanderbilt Learning Technology Center (Schwartz, Lin, Brophy, & Bransford, 1999)**
  Star Legacy is actually a software shell for instruction which incorporates the five basic instructional methods or first principles respectively. The underlying instructional model suggests starting a learning episode by an outlook on the learning content and then the model provides challenges (i.e., problems to be solved). In a next step generating ideas is supposed to activate prior knowledge followed by providing learners with multiple perspectives on a problem. Finally research and revise is a demonstration and application phase followed by an application phase named test your mettle and by an opportunity to demonstrate their solutions to the public. [see also Merrill, 2002, p. 3]

- **4MAT (McCarthy, 1996)**
  Her model includes four distinct activities of instruction: (a) Meaning: Activation of prior knowledge and giving a meaning to the learning content;
(b) Demonstration phase and conceptualizing of knowledge; (c) Application of new knowledge, operationalizing, and practising; (d) Integration of new knowledge into prior knowledge and refining ideas. [see also Merrill, 2002, p. 3-4]

- **Instructional Episode (Andre, 1997)**
  He suggested a model which incorporates (a) and activation phase, (b) an instructional phase, and (c) a feedback phase. [see also Merrill, 2002, p. 4]

- **Multiple Approaches to Understanding (Gardner, 1999)**
  In contrast to a number of instructional theories which focus on problem solving as major foundation of successful learning, Gardner’s model emphasizes the role of “understanding content”. The model comprises four distinct phases of learning: (a) Entry points as form of activation, (b) telling analogies as form of demonstration, (c) approaching the core as a more in-depth form of demonstration, and (d) application. [see also Merrill, 2002, p. 9]

- **Collaborative Problem Solving (Nelson, 1999)**
  Nelson’s theory is in tradition of problem-based learning, emphasizing the role of solving problems. The theory primarily focuses on application of new knowledge and less on demonstration. The core of the theory is nine process activities: (a) build readiness, (b) form and norm groups, (c) determine a problem definition, (d) define and assign roles, (e) engage learners in an interactive collaborative problem solving process, (f) finalize the solution, (g) synthesize and reflect, (h) assessment of products and problem solving processes, and (i) provide closure. [see also Merrill, 2002, p. 9]

- **Constructivist Learning Environments (CLE, Jonassen, 1999)**
  This approach emphasizes problems solving and it includes the first principles (cf. Merrill, 2002) of instruction. [see also Merrill, 2002, p. 10]

- **Four Component Instructional Design Model (4C/ID, van Merrienboer, 1997)**
  This approach is a very comprehensive model of instructional design which incorporates all the first principles (cf. Merrill, 2002). [see also Merrill, 2002, pp. 10-11]

- **Learning by Doing (Schank, 1999)**
  Learning by doing strongly focuses on the application of new knowledge and on learning by application. Schank identifies seven components of learning by doing: (a) learning goals, (b) mission, (c) cover story, (d) role, (e) scenario, (f) operations, (g) resources, and (h) feedback. [see also Merrill, 2002, p. 11]
6. References


