

Chapter 2

Educational Theory

Learning theory is used to support the construction of learning path in e-learning for different types of students using different types of teaching approaches and also the generation of the learning resources as the learning contents. We assess student learning progress to determine their learning qualities. The following theories involve the introduction of learning theory to support our research, e-learning to introduce the research application in this area, learning taxonomy as the criteria of learning outcomes, learning styles for different types of students, learning modes for different types of learning approaches, student assessments for different approaches to evaluate student learning performance, Association Link Network to introduce how learning resources relate to each other, and system development tools of the research to introduce the used programming techniques. Given this information, readers can have a better knowledge background before starting to understand the main research of learning path construction in e-learning and the analysis of student learning progress.

2.1 Learning Theory

Learning theory [Band77] is the foundation of this monograph, which supports all the learning processes and is used to guide the design of learning systems. Learning theory describes how information is absorbed, processed, and retained during the learning process. There are three main categories of learning theory including behaviorism, cognitivism, and constructivism. Behaviorism focuses on achieving the objectively observable behavior by repetition of desired actions. Cognitivism looks beyond behavior to explain how the learning happened in our brain. Constructivism views learning as a process in which a student actively constructs or builds new ideas or concepts. Our monograph is developed based

on the constructivism learning theory. Constructivism learning theory [Coop04, Fran06] requires students to construct knowledge in their own meaning, to build up knowledge concepts based on prior knowledge and their experience, to enhance their learning through social interaction, and to develop learning through authentic tasks. During constructivism learning, students achieve learning outcomes by attempting to address problems when they find their expectations are not met, so they need to resolve the discrepancy between what they expected and what they encountered [Lefo98].

In the learning theory of constructivism, each student is considered as a unique individual with personalized needs, learning styles, learning preferences, knowledge levels, and knowledge backgrounds, which is complexity and multi-dimensional. During a typical constructivist session [Coop04], students work on problems and teachers only intervene them to guide them in the right direction. Students could provide different responses to learning, e.g., they are involved in an active learning process, and they are using critical thinking to challenge, judge knowledge, and learn from it. Under the learning theory, teaching approaches are designed according to these learning outcomes. With the help of techniques in e-learning, the learning process, which emphasizes that knowledge is shared between teachers and students, does not focus on the teacher-centered learning environment, but put more emphasizes on self-paced learning by providing access to education at any time, any place, and taking into account students' differences.

2.2 e-Learning

E-learning aims to support learning and teaching, transfer knowledge and skills through the Web and electronic machines. E-learning techniques provide various forms of electronic tools and platforms, teaching and learning approaches, learning environments, etc. Current research in e-learning mainly focuses on several broad aspects, such as *technology-enhanced learning*, *learning resource organization and standardization*, and *e-learning platforms and tools*. *Technology-enhanced learning* [Wang05] is technology-based learning and instructional systems, where students acquire skills or knowledge with the help of teachers, learning support tools, and technological resources. Technology-enhanced learning investigates the use of information and communication technologies to help students to learn effectively through a course of study by pedagogically making learning contents more accessible and providing students with better learning environments. *Learning resource organization and standardization* [Totk04] design models for organizing learning contents, so that the contents can be easily adopted by different e-learning systems and reused in various instructional contexts. On the other hand, *e-learning platforms and tools* [Dagg07], also known as virtual learning environments (VLE), use a mix of communication technologies and focus on the design and development of the hardware and software components of e-learning systems over the Web 2.0 for two-way interaction. *Adaptive e-learning*

methods [Jere10] tend to find out an effective way to guide students to learn according to students' interests, so that the learning process could be adjusted for different students.

This monograph of learning path construction and the analysis of student learning progress are concerned with learning using electronic devices and the Web. We discuss different types of learning and different types of e-learning systems in this section to help reader to better understand how the learning is carrying out, and more specifically, how the e-learning is carrying out.

2.2.1 Types of Learning

Learning has gone through several stages where learning is traditionally supported by face-to-face teaching, and now with the help of communication and information technologies, new forms of learning, such as web-based learning, have been developed. However, traditional learning does not allow students to learn at any time and at any place, and web-based learning lacks of interaction between teachers and students. Blended learning is developed by combining the traditional learning and web-based learning to provide a better learning approach. Our monograph can be applied to both web-based learning and blended learning by providing a user-friendly intelligent tutoring system to construct learning path as well as to analyze student learning progress.

2.2.1.1 Traditional Learning

Traditional learning is teacher-centered learning, where teachers interact with students face-to-face in classroom. Traditional learning focuses on teaching, not learning. The knowledge taught in traditional education can be used in instructional design, but cannot be used in complex problem solving practices. It simply assumes that what a student has learned is what a teacher has taught, which is not correct in most cases.

2.2.1.2 Web-Based Learning

Web-based learning is self-paced learning, which requires students to access Internet via devices like computers. The learning is beyond traditional learning methodology. Instead of asking students to attend courses and read printed learning materials, students can acquire knowledge and skills through an environment which makes learning more convenient without spatial and temporal requirements. Web-based learning applications consider the integration of user interface design with instructional design and also the development of the evaluation to improve the overall quality of web-based learning environment [Chan07].

Web-based learning is different from the term of computer-based learning, which also uses devices like computers, but does not have to require students to access to Internet during the learning process.

2.2.1.3 Blended Learning

Blended learning combines traditional learning with computer-based learning, which creates a more integrated e-learning approach for both teachers and students. The aim of blending learning is to provide practical opportunities for students and teachers to make learning independent as well as sustainable. There are 3 parameters that should be considered in a blended learning course, which are *the analysis of the competencies*, *the nature and location of the students*, and *the learning resources*. Also, blended learning can be applied to the integration of e-learning with a learning management system using computers in a traditional classroom with face-to-face instruction.

2.2.2 Types of e-Learning

With the help of technologies and electronic media, e-learning makes the teaching and learning more effectively. Teaching and learning could be approached at any time and any place. E-learning systems have actually been well developed and have different types including traditional e-learning system, adaptive e-learning system, intelligent tutoring system, and service-oriented e-learning system. Traditional e-learning [Dagg07] has simplex design which fails to provide more flexible ways of learning, such as personalized learning, active learning, and online interactions between teachers and students. Adaptive e-learning [Shut03] focuses on student characteristics, such as learning styles, knowledge background, and learning preferences, which makes the learning to be applied to different teaching approaches for different types of students. Instructional design system [Gust02] contains 5 phases of *analyze*, *design*, *develop*, *implement*, and *evaluate*, which aims to determine student learning states, define learning outcomes, and provide teaching strategies. Intelligent tutoring system [Murr03] does not only focus on the sequencing mechanisms of curriculum delivery, so that students know how to learn rather than just what to learn, but also applies AI to customize teaching approaches according to student's needs in order to optimize learning of domain concepts and problem solving skills. Service-oriented e-learning [Jamu09, Su07] provides with different Web services, so that both teachers and students can access the e-learning system and use different functionalities. We briefly introduce them as follows:

2.2.2.1 Traditional e-Learning System

Traditional e-learning separates teachers from students and also separates students from students; the teaching and learning carry out over the Internet or through computer-based technologies [Stiu10]. Traditional e-learning cannot provide adaptive learning technologies, which needs a team that has advanced skills, such as programming, graphic design, or instructional design to improve the learning system and requires course creator to create graphics, simulations, and animations. Teacher also needs to design learning contents for constructing courses. Learning management system (LMS) [Brus04] is an integrated traditional e-learning system that supports a number of learning activities performed by teachers and students during the e-learning process. LMS aims to deliver online courses to students and try to keep students' learning progress on the right track, but LMS is not used to create learning contents. Students can use it for learning, communication, and collaboration.

2.2.2.2 Adaptive e-Learning System

Students have different knowledge background, knowledge levels, learning styles, learning preferences, and also different misunderstandings and learning outcomes, etc. It will become a very huge work for teachers to design the learning contents and the learning activities, and to provide with different teaching approaches and different feedbacks. The e-learning system is considered adaptive [Jere10] if it follows student behaviors as well as interprets them, makes conclusions about students' requirements and their similarities, adequately represents them, and finally impacts students with the available knowledge and dynamically manage the learning process. Adaptive e-learning system has the adaptability toward students' needs, the reusability of learning activities, and the effective design of learning contents. Our monograph can be applied to adaptive e-learning system as our research also constructs learning resources for different types of students and designs learning paths to support different teaching approaches.

2.2.2.3 Instructional Design System

Instructional design system is a system of determining student learning state, defining the learning outcomes, and also providing teaching strategies for knowledge transition, which aims to improve learning performance [Reis01]. Instructional design is learner-centered which focuses on current learning states, needs, and learning outcomes of students. The learning outcomes of instructional design reflect students' expectations for the learning, which expect students having the ability of applying knowledge or skill in some learning environments.

The procedure of developing instructional materials provides us the guidance and requirements of designing a qualified e-learning system. The typical instructional design system [Gust02] includes five phases including *analyze*, *design*, *develop*, *implement*, and *evaluate*. *Analyze* phase requires teachers to collect information about students, learning tasks and learning outcomes, and then classify the information to make learning contents more applicable. *Design* phase composes the expected learning outcomes and corresponding tests through learning tasks. *Develop* phase generates learning contents based on the learning outcomes. *Implement* phase refers to how to deliver the instructions for students to learn. *Evaluate* phase ensures that the learning contents can achieve the learning outcomes through both summative and formative assessments.

2.2.2.4 Intelligent Tutoring System

Intelligent e-learning system brings the artificial intelligence (AI) technology to the current e-learning system together and products a personalized, adaptive, and intelligent service to both teachers and students. Intelligent tutoring systems (ITS) use AI to customize teaching approaches according to student's needs, which is trying to optimize learning of domain concepts and problem solving skills. Our monograph can also be applied to ITS, because the proposed work provides adaptive teaching approaches, personalized learning resources, and intelligent student progress indicators. ITS [Murr03] are computer-based instructional systems, with instructional contents organized in the form of learning activities that specify *what to teach* and teaching approaches that specify *how to teach*. They make inferences on student learning progress and offer instructional contents and styles of instruction adaptively. Instructional contents can be broadly categorized into two main types [Bigg07]: declarative knowledge, i.e., facts or concepts, and functioning (procedural) knowledge, i.e., how something works. Early ITSs, such as SCHOLAR [Carb70a], focus only on the modeling of declarative knowledge and cannot properly support the training of procedural and problem solving skills. Newer ITSs, such as DNA [Shut98], incorporate the modeling of functioning knowledge to address this issue.

To identify a suitable teaching approach, an ITS should understand the learning progress of a student and, more ideally, consider student learning styles [Feld88, Li10] as well. In existing ITSs, such student information is commonly maintained as a *student model* [Brus07, Elso93] and updated by some *inference algorithms* [Chen06, Cona02]. Traditionally, the student model is typically formulated in the form of a *knowledge model* [Brow78, Carb70b] to maintain the set of learning activities that a student studies. Student learning progress is then evaluated by checking the portion of expert knowledge that a student has acquired. However, this model fails to formulate errors or misunderstandings made by the student. To address this problem, the bug-based model [Brow78] is proposed, which applies rules to determine the difference between the expected and the actual ways to be

used for problem solving when studying a piece of knowledge. This model essentially evaluates the problems in understanding made by a student. On top of the student model, inference algorithms are applied to determine or predict the student learning performance over a course of study based on some probability information. Popular choices of inference algorithms are the *Bayesian networks* [Cona02], which perform inferences based on some precondition information, particularly the previous learning performance of students, and the *item response theory* [Chen06], which performs inferences based on the probability information of the responses made by students when conducting certain assessments.

2.2.2.5 Service-Oriented e-Learning System

Service-oriented system for e-learning describes a concept of e-learning framework which supports e-learning applications, platforms, or other service-oriented architectures. Service-oriented e-learning system [Jamu09, Su07] provides Web services, such as assessment, grading, marking, course management, metadata, registration, and reporting, in order to produce more functionalities for the e-learning system. It aims to produce reliable Web services that can be applied to different operation systems. Users can access these services through the Web. While our research supports such an e-learning platform where teachers can design and manage adaptive learning paths, personalized learning resources can be generated for each student and also student progress can be graphically presented.

2.3 Learning Taxonomy

Learning taxonomy provides the criteria of assessing student learning performance to see if students can achieve their learning outcomes. Learning outcomes are learning objectives that students are expected to achieve at the end of learning, which could be cognitive, skill-based, and affective learning outcomes. Learning taxonomy [Full07] includes three domains, *cognitive*, *affective*, and *psychomotor*, where each domain evaluates learning outcomes in several levels. Learning taxonomy guides teachers to design courses on the basis of achieving these learning outcomes as well. The most common learning taxonomy is Bloom's taxonomy which we have applied in this monograph. Because it can assess knowledge, attitude, and skills, it can be applied to all disciplines. There are also some other learning taxonomies slightly different from it, such as Gagne's taxonomy, SOLO taxonomy, and Finks taxonomy. Gagne's taxonomy does not only cover the 3 categories of Bloom's taxonomy, but also involve another 2 categories of verbal information, intellectual skills. SOLO taxonomy divides learning outcomes by 5 learning stages rather than independent categories. And Finks taxonomy considers learning as a cycle consisted of 6 aspects. We introduce each of them as follows:

2.3.1 Bloom's Taxonomy

Bloom's taxonomy [Bloo56] provides the criteria for assessments of learning outcomes which could be classified into three domains of knowledge, attitude, and skills, in this way it could be applied to all kinds of subjects. A learning activity should have its own learning outcomes, such as the knowledge level. Students can develop their knowledge and intellect in cognitive domain, attitudes and beliefs in affective domain, and the abilities to put physical and bodily skills to act in psychomotor domain.

The *cognitive* domain refers to intellectual capability, such as knowledge, or think, which has 6 levels from easy to difficulty including recall data, understand, apply, analyze, synthesize, and evaluation. The *affective* domain refers to students' feelings, emotions, and behavior, such as attitude or feel, which has 5 levels from easy to difficulty including receive, responding, value, organization, and internalize. The *psychomotor* domain also has 5 levels from easy to difficulty including imitation, manipulation, develop precision, articulation, and naturalization. The psychomotor domain refers to manual and physical skills, such as skills or do, which was ostensibly established to address skills development relating to manual tasks and physical movement. However, it also concerns and covers business and social skills such as communications and operation IT equipment, for example, public speaking. Thus, psychomotor extends beyond the originally traditionally imagined manual and physical skills.

2.3.2 Gagne's Taxonomy

The learning outcomes of Gagne's taxonomy [Gagn72] is similar to Bloom's taxonomy. However, Gagne's taxonomy divides learning outcomes into five categories, which are verbal information, intellectual skills, cognitive strategies, attitudes, and motor skills. Verbal information is the organized knowledge including *labels and facts* and *bodies of knowledge*. Intellectual skills refer to knowing how to do something including discrimination, concrete concept, rule using, and problem solving. Cognitive strategy is the approach where students control their own ways of thinking and learning. Attitude is an internal state which affects an individual's choice of action in terms of a certain object, person, or event. Motor skills refer to bodily movements involving muscular activity, including the learning outcome to make precise, smooth, and accurate performances with muscle movements. The learning outcomes are normally dependent on each other. There are always combined learning outcomes selected for completing a task.

2.3.3 SOLO Taxonomy

The SOLO taxonomy [Bigg07] stands for structure of observed learning outcomes, which describes the level of a student's understanding of a subject through five stages, and it is able to be used to any subject area. The first stage is *pre-structure* where students just acquire no structured information. The second stage is *uni-structural* where students capture simple and obvious aspects of the subject, but they still have not understood significant aspects. The third stage is *multistructural* where students make a number of relevant independent aspects but cannot connect them. The fourth stage is *relational* where students are able to identify the most important parts of the whole structure. The fifth stage is *extended abstract* where students can generalize another new application based on the structure constructed in the *relational* stage. The SOLO taxonomy is similar to the cognitive domain in the Bloom's taxonomy, which can be used not only in the assessment, but also in designing the curriculum in terms of the learning outcomes.

2.3.4 Finks Taxonomy

Finks taxonomy [Fink03, Fink09] is different from Bloom's taxonomy and SOLO taxonomy, which taxonomy is not hierarchical. It covers broader cross domains, which emphasizes on learning how to learn and includes more affective aspects. The learning process has 6 aspects in a cycle including foundation knowledge, application, integration, human dimensions, caring, and learning how to learn. In the aspect of foundational knowledge, students understand and remember knowledge. In the aspect of application, students train up skills of critical thinking, creative and practical thinking, and problem solving skills. In the aspect of integration, students make connections among ideas, subjects, and facts. In the aspect of human dimensions, students learn and change themselves, understand and interact with others. In the aspect of caring, students identify and change their feelings, interests, and values. In the aspect of learning to learn, students learn how to ask and answer questions, and become self-directed students.

2.3.5 Subsection Summary

We apply Bloom's taxonomy as the learning outcomes in our monograph. There are also a lot of works on Bloom's taxonomy. Reference [Naps02] applies Bloom's taxonomy [Bloo56] as well as other factors as follows: student learning progress, dropout rate, learning time, and student satisfaction. Limongelli et al. [Limo09] only chooses three out of the six levels: knowledge, application, and evaluation as the evaluation criteria. However, these evaluation methods still could

not instantly tell students how to improve. Also, some work [Chen05, Dolo08, Cono05] considered student's ability as performance evaluation. Chen et al. [Chen05] evaluates student abilities based on the student's response to the recommended learning activity and modifies the difficulty levels of all learning activities which are considered as index to rank learning activities in order to update learning paths. However, a student's ability is just given by a single value. In [Dolo08], a student's abilities just limits to programming in Java or .NET, which cannot be applied to all situations. According to the research on learning abilities for evaluating student learning performance, it classifies these learning abilities into eight aspects: leadership, critical thinking, value-based decision making, logical reasoning, problem solving, oral communication skills, written communication skills, and lifelong learning. Each aspect contains several subaspects and making 74 subaspects in total. However, according to the research of psychology [Bart32], human abilities are divided into three groups: language, action, and thought with 22 subattributes in total. We found that there are some attributes that does not consider about, such as imagination, while there are some attributes in psychology that are not suitable to apply to general e-learning, such as speed, strength of power in the action group. Besides [Cono05], also distributes different ability requirements to learning tasks including too many skills (38 skills) without classification, and some of them are overlapped.

2.4 Learning Styles

Our work has developed learning progress indicators which addressed the needs of students with different learning styles. When we assess student learning progress, we expect students to handle different learning environments. If students can well perform different learning activities, they have the ability to handle different learning environments and have a balanced development. A learning style model classifies students according to their behavior patterns of receiving and processing information. Teaching style model classifies instructional methods according to how well they address the proposed learning style components.

According to the research of [Feld88], learning style contains five aspects. From the viewpoint of which type of information students prefer to perceive, there are sensors who prefer to solve problems using standard methods rather than unconventional methods, and intuitors who prefer to use innovated methods rather than repetition. From the viewpoint through which sensory channel external information most effectively perceived is, there are visual students who are sensitive to diagrams and graphs, and auditory students who are sensitive to words and sounds. From the viewpoint of which information organization students are most comfortable with, there are inductive students who are sensitive when given facts and observations, and underlying principles are inferred. Deductive students are sensitive when given principles and consequences and applications are deduced. From the point of view that how students prefer to process information, there are

active students who prefer engagement in physical activity or discussion, or reflective students who prefer introspection. From the point of view that how students progress toward understanding, there are sequential students who learn in continual steps, and global students who learn gradually from the whole knowledge structure to more detailed concepts.

2.5 Learning Modes

In this monograph, we use different learning modes to design teaching approaches for different aims of training students. The learning has various forms, which does not only support individual learning but also support collaborative learning. In our monograph, we also need to use different forms of learning to construct different teaching approaches. Individual learning helps students to train them to solve problems on their own, and collaborative learning helps students to train them teamwork spirit. The most common way of learning is to work individually. Students have to work on their own to solve problems and reach the learning outcomes. Collaborative learning is a type of learning in which two or more people learn something together, where students can make use of peer's learning resources and skills. Collaborative learning includes collaborative writing, group projects, joint problem solving, debates, study teams, and other learning activities. Collaborative learning uses technology to define rules and roles, construct learning tasks, control and monitor the learning process, and support group interactions in a collaborative learning environment.

2.6 Student Assessment

As the aim of learning is to achieve learning outcomes, the learning path is constructed based on learning outcomes. In order to determine if students have achieved their learning outcomes, we need to assess their learning performance. Student assessment measures the level of student achievement on knowledge and abilities. The form of student assessment can be summative or formative [Oscal11]. Information about student learning progress needs to be collected before, during, and after learning some learning activities [Feng09, Oscal11]. Student learning progress can be expressed as growth rate [Bete09, Stec08] and overall improvement [Pets11]. In addition, prediction on student's future learning performance [Hanu05, Wiel10] can also be done. A teacher may review and enhance teaching approaches based on student learning progress [Stec05, Stec08].

By tracking student learning progress and evaluating student learning performance, we can guide students to approach the most appropriate learning activities as well as to help them to improve their learning performance and reach the learning outcomes in the end. Based on previous work, learning outcomes are given

by ranks [Good09, Ma00], scores [Kwas08, Liu05, Yang05], or feedback [Leun07, Guzm07], according to different criteria, such as the levels of acquired knowledge [Good09, Leun07], the spending time and efforts [Good09], the number of correct questions [Chen08] with tests or questionnaires, or learning abilities of students [Dolo08, Leun07, Chen05].

Although [Leun07] can provide an instant feedback on student learning performance, the feedback can only tell if we should provide students the optional materials. In [Huan07], a student knows his/her misconceptions in solving a problem and the student's weak learning activities from a global test. However, this information is not enough to know the student's learning progress and cannot help the student to improve his/her learning performance. In [Ma00], the evaluation results would always be divided to several fuzzy grades from the "best" grade to the "worst" grade, and examples of fuzzy grades include "good," "pass," "fail," etc. Even if a student performs better than the course expectation, the student would still fail as long as the student is worse than the majority of students. In [Chen05], the evaluation tests student's satisfaction on the learning path. However, this work cannot promise the student to reach the learning outcome. Guzman et al. [Guzm07] provide a self-assessment test which can rectify misconceptions and enhance acquired knowledge. With a student's knowledge distribution model, the selected evaluation criteria determines questions and computes the expected variance of the student's posterior knowledge distribution. The test results provide an estimation of the student's knowledge level which is the minimum expected posterior variance. As they need to calculate the correct possibility and the incorrect possibility of a question, the answer has to be either true or false, but these results are too limited for the most types of questions. In short, these methods only consider if students can correctly understand knowledge in one way or another, but they ignore the assessment of balanced developments of students' knowledge and learning abilities.

Existing works [Chen08, Cola10, Huan07] have developed ways to collectively model the students' understanding on knowledge. Huang et al. [Huan07] requires teachers to manually plan two formative assessments for each UoL, and a summative assessment in the end of a learning path. The two formative assessments cover the same knowledge using different questions. The 1st formative assessment calculates students' scores and analyzes their learning situations. The 2nd formative assessment ensures students understanding the concepts rather than memorizing the answers. In [Chen08], questions are manually designed by teachers based on the course materials and stored in the question database. Questions are randomly selected from the database to generate a pretest. The incorrect test results are used to select suitable courseware to plan the learning path. However, these methods require teachers to manually design the test, then [Cola10] provides an automatic method to measure student learning performance by the Bayesian approach, which selects a set of questions associated with every network node to identify if a student can correctly form the knowledge concepts. However, these questions just focus on each single node, which cannot reflect if students can correctly build up the relationships between them.

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