CHAPTER 19—INTELLIGENT TUTORING SYSTEMS: PAST, PRESENT, AND FUTURE

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19.1 **Intro**

(p. 571) Goal of ITS is to communicate its embedded knowledge effectively, not necessarily in an identical manner as human teachers

19.2 **Precursors of ITS**

19.2.1 **Early mechanical systems-**

- Charles Babbage early 1800s) credited with vision of first computer—an analytical engine
- "intelligent machines" dates back to 1926 with Pressey who developed an instructional machine with M/C questions
- mid 1900s with digital computer led way for true artificial intelligent machines (built in ability to make logical decisions)
- Alan Turing developed the "Turing Test" as a means of determining a machine's intelligence

19.2.2 **Programmed Instruction and Computer-Assisted Instruction**

- refers to any instructional methodology that utilizes a systematic approach to problem decomposition and teaching.
- may be within a computer program (i.e. CAI)
- PI fashionable in early 1960s

19.2.3 **Intelligent Computer-Assisted Instruction**

- part of the continuum with CAI

19.2.3.1 **Artificial Intelligence and Cognitive Psychology**

-Def'n: AI is the study of mental faculties through the use of computational models.
- Objective is to design and develop computer systems that solve the same kinds of activities that we deem intelligent
- Relevant parts to ITS include efficient representation, storage, and retrieval of knowledge
- Cog. Psych part by examining how to get a computer to behave intelligently by examining issues related to the representation and organization of knowledge types in human memory

19.2.3.2 **The Nature of Errors**

- traditional concept was that remedial errors occurred because of inaccurate or insufficient knowledge◊ misconceptions where the student is not at the appropriate stage of cognitive development

- next came concept of 'bugs" and the buggy algorithm worked on by Burton & Brown leading to the development of DEBUGGY
- then VanLehn developed Impasses where bugs are the results of unsuccessful attempts to extend existing rules to apply to novel situations
- lastly the concept of situated cognition where the environment acts as a general scaffolding to strengthen the student's first new skills or knowledge structures.

19.2.3.3 **Summary**

- branching a fundamental aspect of PI, CAI, and ICAI

19.3 **Intelligent Tutoring Systems Defined**

- authors' distinction between ICAI and ITS is ITS is a part of ICAI

19.3.1 **Early Specifications of ITS**

- knowledge of the domain
- knowledge of the learner
- knowledge of the teaching strategies

19.3.2 **ITS Components and Relationships**

- mainly problem solving
- starts with student model
- moves to curriculum or expert domain
- then concludes with tutor or inherent teaching strategy

19.3.3 **The "I" in ITS**

- working def'n: of computer-tutor intelligence is that the system must behave intelligently, not actually be intelligent, like a human being

- 1) accurately diagnose students' knowledge structures, skills, and/or styles using principles rather than preprogrammed responses
- 2) adapt instruction accordingly (remediation)

19.4 **The 20-History of ITS**

19.4.1 **Up through the 1970s: Defining the Issues**

- rapid growth of computers
- 'Pong" and 8K RAM normal for PCs

Research issues of the 70s

19.4.1.1 **Real-Time Problem Generation**

- generated problems and learning tasks (not the usual canned problems)

- Uhr developed computer-based learning system that created real time, simple arithmetic problems and vocabulary recall tasks.

19.4.1.2 **Simple Student Modeling**

- BASIC programming language—selected problems based on what the student already knew, which skills to be taught next, and the analysis required

19.4.1.3 **Knowledge Representation**

- SCHOLAR program by Carbonell (often credited as being the first true ITS) used semantic net to represent domain knowledge as well as the student model
- students could ask questions to the computer as well as the computer asking the questions.
- had difficulty with procedural knowledge

19.4.1.4 **Socratic Tutoring**

- believed to involve the learner more actively
- Collins took Socratic dialogues (believed to involve the learner more actively in the learning process) and outline a set of tutorial rules incorporated into a system called WHY (if…then)

19.4.1.5 **Skills and Strategic Knowledge**

- WEST program developed by researcher as Xerox to help students learn/practice skills involved in manipulation of arithmetic expressions

19.4.1.6 **Reactive Learning Environments**

- SOPHIE (sophisticated instructional environment) designed to assist learner in developing electronic trouble shooting skills

19.4.1.7 **Buggy Library**

- developed by Brown and Burton
- a framework for modeling misconceptions underlying procedural error in addition and subtraction where students' errors were represented as the results of 'bugs" in an otherwise correct set of procedures
- DEBUGGY off-line version
- IDEBUGGY on-line version

19.4.1.8 **Expert Systems and Tutors**

- medical teaching models such as MYCIN specific for meningitis and GUIDON that interfaced with it

19.4.1.9 **Overlay Models/Genetic Graph**

- Overlay model is one of a novice-expert difference model representing missing conceptions
- e.g. WUSOR

19.4.2 **1980s: Standardized Approached and Environments**

- enormous growth
- everyone wanted part of growth, but little cared about efficacy
- Sleeman outline 4 main problems

feedback specificity (not enough feedback to learner)
nonadaptability (not student's conceptual framework)
atheoretical framework (no cognitive theory basis)
restrictive environment (user interaction limited)

19.4.2.1 **Model Tracing**

- Developed by Anderson and colleagues as Carnegie-Mellon University
- based on Anderson's cognitive theory
- e.g. LISP and geometry tutors
- learning occurs in chunks
- students stopped with errors, not allowed to learn from mistakes
- good for procedural knowledge, not for ill-structured domains such as economics or creative writing

19.4.2.2 **More Buggy-Based Systems**

- system provides specific feedback
- student's error must match stored error
- e.g. PROUST (diagnose errors in Pascal programs)
- e.g. PIXIE (diagnostic model for determining sources of error in algebra problems—mal-rules)

19.4.2.3 **Case-Based Reasoning (CBR)**

- goal of ITS should be teaching cases and how to index them
- works well in ill-structured domains
- suggests approximate answers to complex problems
- processes—indexing (labeling new experiences for future retrieval) and adaptation (changing a retrieved case to fit a situation)
- limitation is problem of anticipating and representing a sufficient number of cases to be catalogued

19.4.2.4 **Discovery Worlds**

- designed to allow students to acquire knowledge and skills on their own
- usually a computer simulation
- allows for great adaptability

- drawback is not all persons are skilled in the requisite inquiry behavior necessary to achieve success

19.4.2.5 **Progression of Mental Models**

- incorporation of AI research on mental models and qualitative reasoning to develop QUEST as well as 'Thinker Tools
- guides students through microworlds pointing out inconsistencies

19.4.2.6 **Simulations**

- useful whenever real objects are involved in learning or training
- lack strong theoretical basis

19.4.2.7 **Natural Language Processing (NLP)**

- found with development of SOPHIE with the *Semantic Grammar* by Richard Burton
- with animations and immersions into virtual worlds, new prospects are held for immersive language learning

19.4.2.8 **Authoring Systems**

- goal to give relative computer novices a software toolkit to take advantage of the power of computers in designing instruction
- Miller and Lucado were among the first to integrate the power of CBT authoring environments with ITS
- DARPA (a unique consortium of Apple, Houghton-Mifflin, Beverly Woolf, and John Anderson) developing next generation of authoring tools

19.4.3 **1990s: Great Debates**

- Hot topics--
    1. How much learner control should be allowed?
    2. Should learners interact with ITS individually or collaboratively?
    3. Is learning situated, unique, and ongoing or is it more symbolic following the information-processing model?
    4. Does VR uniquely contribute to learning beyond CAI, ITS, or even multimedia?

19.4.3.1 **Degree of Learner Control**

- 2 perspectives on a continuum
    1. develop a computerized environment containing assorted tools and allow learners to explore and learn independently
    2. develop straightforward learning environments with no digressions permitted
- learner control depends on factors such as subject matter, desired knowledge or outcome, incoming aptitudes, etc.

- concept to merge with interactive learning environments◊ bi-modus learning environment
- Coached practice environments such as Sherlock (provides apprenticeship training with intelligent instructional systems)
- Salomon promotes idea of Cognitive tools that at manipulated by students as instruments that promote constructive thinking◊ enhancing cognitive operations
- Conclusion: midpoint between and movable depending on learner needs

19.4.3.2 **Individual vs. Collaborative Learning**

- Traditionally individual learning
- Collaboration def'n: a process by which individuals negotiate and share meanings relevant to the problem-solving task at hand
- more research needed

19.4.3.3 **Situated Learning Controversy**

- also called situated action and situated cognition
- 2 positions:
    1. Situated cognition where learning is a process of creating representation, inventing languages, and formulating models for the first time
    2. Information processing where learning is a progression from declarative knowledge to procedural skills, to automatic skills depending on enablers (what is already known and can transfer) and mediators (cognitive processes)
- to gap between these Shute and Gawlick-Grendell developed the series of statistics modules—*Stat Lady*
- "anchored instruction" an attempt by a group at Vanderbilt to actively engage learners in the learning process by situating instruction in interesting and real-world problem solving environments◊ authentic-feeling environments

19.4.3.4 **Virtual Reality and Learning**

- changes relationships between learning and experience, emphasizing perception
- epitomized the notion of experiential learning
- research varies if knowledge and skills are acquired and transferable to real world situations
- promise in microworld for physics and other science instructions
- state "As to the questions of whether the delivered 'bang' is worth the bucks, the jury is still out."

19.5 **ITS Evaluations**

- relatively few evaluations available

- little agreement as to the standard approach for designing and assessing

19.5.1 **Six ITS Evaluations**

19.5.1.1 **The LISP Tutor**
- instructing LISP programming skills

19.5.1.2 **Smithtown**
- a discovery world that teaches scientific inquiry skills in microeconomics

19.5.1.3 **Sherlock**
- a tutor for avionics troubleshooting

19.5.1.4 **Pascal ITS ("Bridge")**
- teaching Pascal programming

19.5.1.5 ***Stat Lady***
- instructing statistical procedures

19.5.1.6 **Anderson Geometry Tutor**
- environment for proving geometry theroms

19.5.2 **Conclusions from the Six Evaluation Studies**
- all very positive for efficacy for ITS
- selection bias an issue
- authors aware of unpublished studies demonstrating failure
- 7 steps of evaluating ITS by Shute and Regian
    1. delineate goal of the tutor
    2. define goals of the study
    3. select the appropriate design to meet the goals
    4. instantiate the design with appropriate measures, number, and type of subjects and control groups
    5. make careful logistical preparations for conducting the study
    6. pilot test tutor and other aspects of the study
    7. plan primary data analysis concurrent with planning the study

19.6 **Future ITS Research and Development**

19.6.1 **Future 1: Immersive Learning Environments Evolve from ITS**
- incorporate VR
- differentiate from 2-D simulation by results of immersion and interaction

19.6.2 **Future 2: Traditional ITS Disappear; Specific Cognitive Tools Dominate**

- ITS may disappear in the future because the student model may be wrong framework around which to build good learning machines
- second reason is the term 'intelligence" which brings up philosophical issues related to the nature of intelligence

19.6.3 **Future 3: Distance Learning**

- would invariably include VR
- need to make a fundamental change in thinking about education to include everyone, all ages and available in all places

19.6.4 **Future 4: Individualized Learning is Out; Collaborative Learning is In**

- belief that collaboration is better than individualized learning
- computers allowing for high level social interaction

19.6.5 **Future 5: The ITS Approach Continues; Becoming truly Intelligent**

- more controlled research needed in areas of intelligence: the domain expert, the student model, and the tutor

19.7 **Conclusions**

- new approaches to education provides direction for ITS research

New◊	Student-directed explorations	(vs. teacher)
	Interactive modes of instruction	(vs. didactic)
	Extended, multidisciplinary instruction	(vs. short & on one subject)
	Collaborative work	(vs. individual)
	Teacher as facilitator	(vs. as knowledge dispenser)
	Heterogeneous groupings	(vs. ability groupings)
	Performance-based assessment	(vs. factual knowledge & discrete skills)

- changing terminology from ITS to advanced automated instructional systems. Other terms include interactive learning environments, cognitive tutors, individualized teaching systems, computer-assisted learning, automated-instructional support systems, computer-based learning environments, immersive tutoring systems, knowledge communication systems, computer tools, etc.
- no accepted def'n of what comprises computer intelligence
-constraints:

1. cost and power of computers
2. pragmatic and theoretical knowledge of how best to employ them