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See http://helios.hampshire.edu/%7EtjmCCS/atoolsbook/ for info about the book.

Figures and Appendicis from Book Chapter:

TOM MURRAY

Chapter 17

AN OVERVIEW OF INTELLIGENT TUTORING SYSTEM AUTHORING TOOLS:

Updated Analysis of the State of the Art

Abstract. This paper consists of an in-depth summary and analysis of the research and development state of the art for intelligent tutoring system (ITS) authoring systems. A seven-part categorization of two dozen authoring systems is given, followed by a characterization of the authoring tools and the types of ITSs that are built for each category. An overview of the knowledge acquisition and authoring techniques used in these systems is given. A characterization of the design tradeoffs involved in building an ITS authoring system is given. Next the pragmatic questions of real use, productivity findings, and evaluation are discussed. Finally, I summarize the major unknowns and bottlenecks to having widespread use of ITS authoring tools.

Table 1: ITS Authoring Tools by Category ([brackets] refer to Chapter numbers)

CATEGORY	**AUTHORING SYSTEMS**
1. Curriculum Sequencing and Planning	Swift/DOCENT, IDE, ISD Expert, Expert CML
2. Tutoring Strategies	REDEEM (& COCA) [8], Eon [11], GTE
3. Simulation-Based Learning	SIMQUEST [1], XAIDA [2], RIDES[3], DIAG [5], Instructional Simulator [7]
4. Domain Expert System	Demonstr8 [4], DIAG [5], D3 Trainer, Training Express
5. Multiple Knowledge Types	XAIDA [2], DNA [6], Instructional Simulator & IDVisualizer [7], ID-Expert, IRIS [9], CREAM-Tools [10], ,
6. Special Purpose	IDLE-Tool/Imap/Indie [12], LAT [14], BioWorld Case Builder, WEAR
7. Intelligent/Adaptive Hypermedia	InterBook [13], MetaLinks, CALAT, GETMAS, TANGOW, ECSAIWeb

Table 2: ITS Authoring Tool Strengths and Limitations by Category

CATEGORY	STRENGTHS	LIMITS	VARIATIONS
Curriculum Sequencing and Planning	Rules, constraints, or strategies for sequencing courses, modules, presentations	Low fidelity from student's perspective; shallow skill representation	Whether sequencing rules are fixed or authorable; scaffolding of the authoring process
Tutoring Strategies	Micro-level tutoring strategies; sophisticated set of instructional primitives; multiple tutoring strategies	(same as above for most systems)	Strategy representation method; source of instructional expertise
Device Simulation and Equipment Training	Authoring and tutoring matched to device component identification, operation, and troubleshooting	Limited instructional strategies; limited student modeling; mostly for procedural skills	Fidelity of the simulation; ease of authoring
Domain Expert System	Runnable (deeper) model of domain expertise; fine grained student diagnosis and modeling; buggy and novice rules included	Building the expert system is difficult; limited to procedural and problem solving expertise; limited instructional strategies	Cognitive vs. performance models of expertise
Multiple Knowledge Types	Differential pre-defined knowl. representation and instructional methods for facts, concepts, and procedures, etc.	Limited to relatively simple fact, concepts, and procedures; pre-defined tutoring strategies	Inclusion of intelligent curriculum sequencing; types of knowledge/tasks supported
Special Purpose	Template-based systems provide strong authoring guidance; fixed design or pedagogical principles can be enforced	Each tool limited to a specific type of tutor; inflexibility of representation and pedagogy	Degree of flexibility
Intelligent/ Adaptive Hypermedia	WWW has accessibility & UI uniformity; adaptive selection and annotation of hyperlinks	Limited interactivity; limited student model bandwidth	Macro vs. micro level focus; degree of interactivity

Table 3: Degree of use of ITS authoring tools

1. Early prototypes and proofs of concept	Demonstr8, Expert-CML, IRIS, Training Express, BioWorld Case Builder, WEAR
2. Evaluated or used prototypes	DNA, Eon, IDLE-Tool, LAT, GTE, MetaLinks, ISD-Expert
3. Moderately evaluated or used	Electronic Trainer, REDEEM, XAIDA, D3 Trainer, DIAG, CREAM-Tools, Interbook, Swift
4. Heavily used (relatively)	RIDES, SIMQUEST, IDE[1], CALAT

Table: Knowledge acquisition methods:

Scaffolding knowledge articulation with models Embedded knowledge and default knowledge Knowledge management Knowledge visualization Knowledge elicitation and work flow management Knowledge and design validation Knowledge re-use Automated knowledge creation

APPENDIX (SEE NEXT PAGE)

[1] Though IDE was one of the most heavily used systems, it was also one of the earliest. IDE is now a "legacy system," since it runs on obsolete software (NoteCards) and does not incorporate multimedia capabilities that are now de rigueur.

APPENDIX

Below is a table of the ITS authoring tools discussed in this paper, with selected references for each.

BioWorld-Case Builder	Lajoie, S., Faremo, S. & Wiseman, J. (2001). A knowledge-based approach to designing authoring tools: From tutor to author. In *Proc. of Artificial Intelligent in Education*, J.D. Moore C. Redfield, L.W. Johnson (Eds). ISO Press, pp77-86.
CALAT (& CAIRNEY)	Kiyama, M., Ishiuchi, S., Ikeda, K., Tsujimoto, M. & Fukuhara, Y. (1997). Authoring Methods for the Web-Based Intelligent CAI System CALAT and its Application to Telecommunications Service. In the *Proceedings of AAAI-97* , Providence, RI.
CREAM-TOOLS	See Chapter 10 in this volume. Frasson, C., Nkambou, R., Gauthier, G., Rouane, K. (1998). An authoring model and tools for curriculum development in intelligent tutoring systems. Working Paper available from the authors. Nkambou, R., Gauthier, R., & Frasson, M.C. (1996). CREAM-Tools: an authoring environment for curriculum and course building in an ITS. In *Proceedings of the Third International Conference on Computer Aided Learning and Instructional Science and Engineering*. New York: Springer-Verlag.
D3-TRAINER	Schewe, S., Reinhardt, B., Bestz, C. (1999). Experiences with a Knowledge Based Tutoring System for Student Education in Rheumatology. In *XPS-99: Knowledge Based Systems: Survey and Future Direction, 5th Biannual German Conference* on Knowledge Based Systems, Lecture Notes in Artificial Intelligence 1570, Springer. Puppe, F., Reinhardt, B. (1996). Generating Case-oriented training from Diagnostic Expert Systems. In *Machine Mediated Learning* 5 (3&4), 199-219. Reinhardt, B. (1997). Generating Case-oriented Intelligent tutoring systems. *In Proc. of AAAI Fall Symposium, ITS Authoring Systems,* November 1997.
DEMONSTR8 (& TDK, PUPS)	See Chapter 4 in this volume. Blessing, S.B. (1997). A programming by demonstration authoring tool for model tracing tutors. *Int. J. of Artificial Intelligence in Education*. Vol. 8 , No. 3-4, pp 233-261. Anderson, J. R. & Pelletier, R. (1991). A development system for model tracing tutors. In *Proc. of the International Conference on the Learning Sciences*, Evanston, IL, 1-8. Anderson, J. & Skwarecki, E. (1986). The Automated Tutoring of Introductory Computer Programming. *Communications of the ACM*, Vol. 29 No. 9. pp. 842-849.
DIAG (& ReAct, DM3)	See Chapter 5 in this volume. Towne, D.M. (1997). Approximate reasoning techniques for intelligent diagnostic instruction. *International J. of Artificial Intelligence in Education.* Vol. 8 , No. 3-4, pp. 262-283. Towne, D.M. (2002). Advanced Techniques for IETM Development and Delivery, Proceedings Human Factors and Ergonomics Society, 46th Annual Meeting, Baltimore, MD, October 3, 2002.
DNA/SMART	See Chapter 6 in this volume. Shute, V.J. (1998). DNA - Uncorking the bottleneck in knowledge elicitation and organization. *Proceedings of ITS-98*, San Antonio, TX, pp. 146-155. Shute, V. J., Torreano, L. A., and Willis, R. E. (2000). Tools to aid cognitive task analysis. In S. Chipman, V. Shalin, & J.

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ECSAIWeb	Sanrach, C. & Grandbasien, M. (2000). ECSAIWeb: A Web-based authoring system to create adaptive learning systems. *In Proceedings of Adaptive Hypermedia 2000.*
EON (& KAFITS)	See Chapter 11 in this volume. Murray, T. (1998). Authoring knowledge-based tutors: Tools for content, instructional strategy, student model, and interface design. *J. of the Learning Sciences*, Vol. 7. No. 1, pp. 5-64. Murray, T. (1996). Special Purpose Ontologies and the Representation of Pedagogical Knowledge. *In Proceedings of the International Conference on the Learning Sciences,* (ICLS-96), Evanston, IL, 1996. Charlottesville, VA: AACE. Murray, T. (1996). From Story Boards to Knowledge Bases: The First Paradigm Shift in Making CAI "Intelligent.". Proceedings of the ED-Media 96 Conference, Boston, MA, June 1996, pp. 509-514.
EXPERT-CML	Jones, M. & Wipond, K. (1991). Intelligent Environments for Curriculum and Course Development. In Goodyear (Ed.), *Teaching Knowledge and Intelligent Tutoring*. Norwood, NJ: Ablex.
GETMAS	Wong, W.K. & Chan, T.W. (1997). A Multimedia authoring system for crafting topic hierarchy, learning strategies, and intelligent models. *International J. of Artificial Intelligence in Education*, Vol. 8, No 1, pp. 71-96.
GTE	Van Marcke, K. (1998). GTE: An epistemological approach to instructional modeling. *Instructional Science*, Vol. 26, pp 147-191. Van Marcke, K. (1992). Instructional Expertise. In Frasson, C., Gauthier, G., & McCalla, G.I. (Eds.) *Procs. of Intelligent Tutoring Systems* '92. New York: Springer-Verlag.
Instructional Simulator (&Electronic Textbook, IDVisualizer, IDXelerator, ID-EXPERT, Electronic Trainer, ISD-Expert)	See Chapter 7 in this volume. Merrill, M.D., & ID2 Research Group (1998). ID Expert: A Second generation instructional development system. *Instructional Science*, Vol. 26, pp. 243-262. Merrill, M. D. (2001). Components of instruction: toward a theoretical tool for instructional design. *Instructional Science*. 29(4/5), 291-310. Mills, R. J., Lawless, K. A., Drake, L., & Merrill, M. D. (in press). Procedural knowledge in a computerized learning environment.
IDE (& IDE Interpreter)	Russell, D. (1988). "IDE: The Interpreter." In Psotka, Massey, &Mutter (Eds.), *Intelligent Tutoring Systems, Lessons Learned*. Hillsdale, NJ:Lawrence Erlbaum. Russell, D., Moran, T. & Jordan, D. (1988). The Instructional Design Environment. In Psotka, Massey, & Mutter (Eds.), *Intelligent Tutoring Systems, Lessons Learned*. Hillsdale, NJ: Lawrence Erlbaum.
IDLE-Tool (& IMAP, INDIE, GBS-architectures)	See Chapter 12 in this volume. Bell, B. (1998). Investigate and decide learning environments: Specializing task models for authoring tools design. *J. of the Learning Sciences*, Vol. 7. No. 1. Jona, M. & Kass, A. (1997). A Fully-Integrated Approach to Authoring Learning Environments: Case Studies and Lessons Learned. In the *Collected Papers from AAAI-97 Fall Symposium workshop Intelligent Tutoring System Authoring Tools*. AAAI-Press. Dobson, W.D. & Riesbeck, C.K. (1998). Tools for incremental

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InterBook (& ELM-Art, NetCaoch)	See Chapter 13 in this volume. Brusilovsky, P., Schwartz, E., & Weber, G. (1996). A Tool for Developing Adaptive Electronic Textbooks on WWW. *Proc. of WebNet-96*, AACE. Brusilovsky, P, Schwartz, E. & Weber, G. (1996). ELM -ART: An Intelligent Tutoring System on the Work Wide Web. *In Proceedings of ITS-96,* Frasson, Gauthier, Lesgold (Eds.), Springer: Berlin, 1996. pp. 261-269.
IRIS	See Chapter 9 in this volume. Arruarte, A., Fernandez-Castro, I., Ferrero, B. & Greer, J. (1997). The IRIS shell: How to build ITSs from pedagogical and design requisites. *International J. of Artificial Intelligence in Education*. Vol. 8 , No. 3-4, pp. 341-381.
LAT (LEAP Authoring Tool)	See Chapter 14 in this volume. Sparks, R. Dooley, S., Meiskey, L. & Blumenthal, R. (1999). The LEAP authoring tool: supporting complex courseware authoring through reuse, rapid prototyping, and interactive visualizations. *Int. J. of Artificial Intelligence in Education.* Dooley, S., Meiskey, L., Blumenthal, R., & Sparks, R. (1995). Developing reusable intelligent tutoring system shells. In AIED-95 workshop papers for Authoring Shells for Intelligent Tutoring Systems.
MetaLinks	Murray, T., Condit, C., & Haaugsjaa, E. (1998). MetaLinks: A Preliminary Framework for Concept-based Adaptive Hypermedia. *Workshop Proceedings from ITS-98 WWW-Based Tutoring Workshop*., San Antonio, Texas, 1998.
REDEEM (& COCA)	See Chapter 8 in this volume. Major, N., Ainsworth, S. & Wood, D. (1997). REDEEM: Exploiting symbiosis between psychology and authoring environments. *International J. of Artificial Intelligence in Education*. Vol. 8 , No. 3-4, pp. 317-340. Major, N. (1995). Modeling Teaching Strategies. *J. of AI in Education*, 6(2/3), pp. 117-152. Major, N.P. & Reichgelt, H (1992). COCA - A shell for intelligent tutoring systems. In Frasson, C., Gauthier, G., & McCalla, G.I. (Eds.) *Procs. of Intelligent Tutoring Systems '92*. New York: Springer-Verlag.
RIDES (& IMTS, RAPIDS, and see DIAG)	See Chapter 3 in this volume. Munro, A., Johnson, M.C., Pizzini, Q.A., Surmon, D.S., Towne, D.M, & Wogulis, J.L. (1997). Authoring simulation-centered tutors with RIDES. *International J. of Artificial Intelligence in Education*. Vol. 8 , No. 3-4, pp. 284-316. Towne, D.M., Munro, A., (1988). The Intelligent Maintenance Training System. In Psotka, Massey, & Mutter (Eds.), *Intelligent Tutoring Systems, Lessons Learned*. Hillsdale, NJ: Lawrence Erlbaum.
SIMQUEST (& SMISLE)	See Chapter 1 in this volume. Jong, T. de & vanJoolingen, W.R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research*, Vol. 68 No. 2, pp. 179-201. Van Joolingen, W.R. & Jong, T. de (1996). Design and implementation of simulation-based discovery environments: The SMISLE solution. *Int. J. of Artificial Intelligence in Education* 7(3/4). pp. 253-276.

Smart Trainer (& FITS, ontology-based tools)	Ikeda, M. & Mizoguchi, R. (1994). FITS: A Framework for ITS--A computational model of tutoring. J. of Artificial Intelligence in Education 5(3) pp. 319-348. Mizoguchi, R., Sinitsa, K., Ikeda, M. (1996). Knowledge Engineering of Educational Systems for Authoring System Design. In Proceedings. of EuroAIED-96, Lisbon, pp. 593-600. Ikeda, M., Seta, K. & Mizoguchi, R. (1997). Task ontology makes it easier to use authoring tools. Proc. of IJCAI-97, Nagoya, Japan. Mizoguchi, R. & Bourdeau, J. (2000). Using ontological engineering to overcome common AI-ED problems Int. J. of Artificial Intelligence and Education, Vol. 11. pp 107-121. Yayashi, Y., Ideda, M., Seta, K., Kakusho, O. & Mizoguchi, R. (2000). Is what you write what you get?: An operational model of training scenario. Proc. of Intelligent Tutoring Systems 2000.
Swift (& DOCENT, Study)	Winne P.H. (1991). Project DOCENT: Design for a Teacher's Consultant. In Goodyear (Ed.), *Teaching Knowledge and Intelligent Tutoring*. Norwood, NJ: Ablex. Winne, P. & Kramer, L. (1988). "Representing and Inferencing with Knowledge about Teaching: DOCENT." *Proceedings of ITS-88*. June 1988,Montreal, Canada.
TANGOW	Carro, R.M., Pulido, E.., Rodriquies, P. (2002). *An authoring tool that automates the process of developing task-based adaptive courses on the web.* J. of AI and Education.
TRAINING EXPRESS	Clancey, W. & Joerger, K. (1988). "A Practical Authoring Shell for Apprenticeship Learning." *Proceedings of ITS-88*, 67-74. June 1988, Montreal.
WEAR	Virvou, M & Moundridou, M. (2001). Adding an instructor modeling component to the architecture of ITS authoring tools. *Int. J. of Artificial Intelligence in Education* 12(2), pp 185-211.
XAIDA	See Chapter 2 in this volume. Hsieh, P., Halff, H, Redfield, C. (1999). Four easy pieces: Developing systems for knowledge-based generative instruction. *Int. J. of Artificial Intelligence in Education.* Wenzel, B., Dirnberger, M., Hsieh, P., Chudanov, T., & Halff, H. (1998). Evaluating Subject Matter Experts' Learning and Use of an ITS Authoring Tool. *Proceedings of ITS-98*, San Antonio, TX, pp. 156-165. Redfield, C.L., (1996). "Demonstration of the experimental advanced instructional design advisor." In the *Third International Conference on Intelligent Tutoring Systems*, Montreal, Quebec, Canada, June 12-14, 1996