

Instructional Design Agents – An Integration of Artificial Intelligence and Educational Technology

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Abstract: The purpose of this paper is to introduce a project whose goal is to design and develop a productivity tool which helps academic instructors in their course preparation. This tool will be composed of a number of “instructional design agents”, which combine techniques in human-computer interaction, artificial intelligence and educational theory. The first of these agents is based on Bloom’s Taxonomy, and a brief overview of this work in progress is presented.

Introduction

In today's rapidly changing academic environment, the role of university professors is also increasing in complexity. While the three core areas of faculty evaluation are still typically teaching, service and professional development/research, in reality, there are many additional responsibilities that are embedded in these core areas. For example, faculty are not only responsible for the more traditional tasks of preparation and delivery of course materials, but they are also expected to devise and choreograph appropriate "active learning" activities, to incorporate new technologies such as multimedia and the Internet, and to participate in seemingly endless cycles of self- and program assessment and evaluation, to name just a few. In addition to the conduct of their own professional lives, it appears that faculty are also to be held accountable for students' learning, even though increasing class sizes and shrinking resources make it harder and harder to monitor and adjust in such an individualized manner. It is becoming more and more difficult to lead a "scholarly" life, particularly at institutions where teaching is the primary activity. In fact, even there, it is almost impossible to find the time to devote to thorough *a priori* course design, development and improvement. Traditionally, university faculty are trained to be highly skilled content experts in the process of obtaining a Ph.D. Training for job duties in the classroom, however, has been typically left to chance (e.g., receiving training as a teaching assistant), and/or the instructor's own initiative. Even with some amount of training or experience, most university faculty are not necessarily fluent with either a process for instructional design or the many education-related theories of learning that describe the impact of the instruction or teaching style on the students' learning experiences.

Furthermore, in this age of technology, there is a surprising paucity of effective tools available to the instructor to help bridge this gap in knowledge. Today's educational "productivity" tools in the academic environment center around web and slide authoring tools, generation of automated tests and communication-enabling technologies (e.g.,

email, electronic forums, video-conferencing, etc.) (The equivalent of this ten years ago might have been to say that the typewriter or a word-processor and a thermal transparency machine were "productivity" tools.) If faculty are to keep abreast of the changing face of education, it is our contention that they should also then be provided with a suite of tools, preferably on their desktop, which will assist them in critical tasks such as: formulation and organization of course content, design of classroom activities, and delivery of course artifacts.

Our research group is therefore currently working on the design and development of a set of such tools called "Instructional Design Agents" (IDA), and this paper describes the work in progress on this project. It is an interdisciplinary effort that aims to produce intelligent interactive support agents for instructional design in an academic environment. Our approach is to apply practical and theoretical aspects of human-computer interaction, artificial intelligence, cognitive science, educational psychology and educational technology to the problem of helping faculty become more effective and efficient in their roles as course designers, developers and managers. We have adopted a user-centered approach to this project, and have identified four initial categories of activity: 1) the conduct of detailed interviews with course instructors, and observations of them in the processes of both designing and delivering courses, 2) in-depth cognitive, task and content analyses of a specific set of courses, 3) rapid prototype development of a number of small, dedicated stand-alone agents, each of which focuses on some aspect of instructional design theory (e.g., Bloom's Taxonomy, Learning Styles and Multiple Intelligences, to name a few), and 4) deployment of these agents in the academic community for feedback and iterative improvement. Our next goal is then to combine these individual agents into an integrated intelligent desktop agent which will interact with an instructor to assist in development of a course from the initial outline, through the analysis and organization of the content, to the production of educational artifacts for each class session (i.e., lecture notes, interactive class activities, multimedia presentations, web-based documents and animations, etc.). With such an agent to provide basic support, particularly in the early time-consuming content development and structuring phases, the instructor would then be free to address the more creative aspects of course delivery, and to devote more time to individual student interaction. Our emphasis at this time is to provide collaborative assistance for the instructor, rather than the automatic generation of "ideal" course outlines.

A longer-term goal is to incorporate a learning component in which the agent obtains feedback on the outcomes of its recommendations, and then provides improved suggestions the next time. If multiple instructors are using them, the agents could even learn from each other, comparing notes, and sharing successes and failures with their human counterparts.

Related Work

If we turn to the field of Instructional Systems Design (ISD), we find a domain in which many of these activities have already been formalized into models. They typically consist of five basic processes: analysis, design, development, implementation and evaluation, which are then configured in a variety of ways. (see Gagne et al. 1992 or Seels & Glasgow 1998) . In addition to the large sector of professionals who have made a career out of implementing instructional design, a number of high-powered computer-based products are also available in the marketplace. However, the current lack of such facilities (either human or computer-based) in the daily professional lives of most academic faculty suggests at least two major obstacles: 1) access to formal instructional design software packages and/or ISD professionals is very expensive -- certainly beyond the reach of most academic faculty; (ironically, this problem is exacerbated at institutions whose primary mission is teaching, where funds are usually limited and there is little opportunity to invest in such high cost "facilities" for faculty); 2) it appears that the most successful work in the ISD field has focused on development of industry-style training courses, rather than academic-style teaching/learning courses. Although many researchers in the field of ISD also mention academic content in their descriptions of ISD models, it is often as an aside, and it's not clear that these systems-oriented process models really fit the goals, objectives and desired outcomes of academic course delivery. Seels and Glasgow discuss this in relation to public school implementation:

"Although ISD has been adopted by many corporations, the military, and many government agencies, the impact of ISD in public schools has been low. Some of the reasons for this low impact are that (a) the responsibility and authority over instruction are vested in the teacher's direct contact with students, rather than in the development of systematically designed materials; (b) the rigidity of the daily schedules are defined in terms of hours spent in a classroom with a teacher, rather than the learning outcomes achieved,

and (c) the amount of discretionary funding available to support systematically designed technology-based instruction is low (Seels & Glasgow 1998).”

Although the above quotation only mentions public schools, it seems that ISD impact is also poorly represented in the higher education environment, possibly for similar reasons. This suggests that perhaps these techniques and models do not fit the realities of the academic world, although there are some who would say that the academic world should be changed to be more in line with the ISD kinds of approaches.

In industrial training settings, where learning objectives frequently correspond to concrete, well-defined job-related skills, computerized systems, which implement the linear configurations of the majority of instructional design models, may be extremely effective. However, it is our hypothesis that in the more traditional academic setting of higher education, activities such as course design may be modeled more appropriately as opportunistic problem solving, similar to other complex domains such as architectural design or medical diagnosis. That is, the problem is too complex, uncertain and unspecified to be easily tackled in a procedural or algorithmic fashion. Furthermore, there is no one necessarily "right" answer (i.e., a perfect complete course specification) -- a partial or less than optimal solution may be the best we can do, given the various constraints which impact not only the design process, but the final delivery as well. Rather, the instructor thinks about different aspects of the problem almost in parallel, and "islands of partial solutions" develop and compete with each other for the person's cognitive attention until eventually there is a sufficient amount of structure from which to go forward. The instructional design model most closely related to this approach is that of (Kemp et al. 1998), which has nine design elements that can be approached by different paths, and which are surrounded by two outer ovals, which indicate revisions occurring throughout the process (similar to that of user-centered design in the human-computer interaction community).

Bloom's Taxonomy Agent

The first Instructional Design Agent under development in our project is based primarily on Bloom's Taxonomy, and we are using this as a basis to explore a number of design issues:

- how can theories related to instructional design be used proactively by instructors to articulate, structure, design and implement academic courses?
- what kind of knowledge is needed by the agent not only to capture the concepts of the theory but also to understand and respond to the problem-solving behaviors of the instructor in the process of design?
- what kinds of data/knowledge representations are needed to structure the relationships between course content, theoretical constructs and classroom artifacts?
- what kinds of information visualization techniques can be employed most effectively to allow instructors to: a) navigate their design problem space, b) to detect patterns in the relationships of concepts, and c) engage in "what if" scenarios, where the effects of changes in certain parameters (e.g., order of course material) on other course components are immediately visible?
- can we effect a noticeable shift of cognitive load so that the instructor can operate primarily as a content expert, and have the agent provide the infrastructure and expertise which a human instructional design assistant might otherwise afford?

The Taxonomy of Educational Objectives was developed in the 1950s by a team of educational psychologists, headed by Benjamin Bloom, as a tool for classifying educational goals and outcomes (Bloom et al. 1956). Of the three domains of behavior described in the original work, the cognitive domain is the one most associated with educational outcomes, and it is described as a hierarchy of six major components, each increasing in complexity: knowledge, comprehension, application, analysis, synthesis and evaluation. From the literature it appears that use of this particular taxonomy as a context for designing instruction has focused primarily on classifying goals, objectives and/or test items once they have been devised (see Jonassen et al. 1989). This suggests that the instructor has somehow been able to break down the components of the course into atomic pieces, which then can be labeled. However, it is our contention that such detailed *a priori* analysis of course content and delivery strategies is rarely accomplished, at least in the first few years of teaching a course. This suggests that devising the course outcomes, goals and objectives themselves (i.e., developing the mental model of the course) is a challenging task, and that perhaps the intelligent assistance agent should first aim to help the instructor articulate these preliminary building blocks. In order to accomplish this, our agent embodies Bloom's Taxonomy as an interactive design tool, which

should help the instructor formulate an effective mental model of the course concepts, rather than just as a diagnostic tool for a pre-existing model.

Initial System Design

In order to further constrain the problem, we have selected the freshman computer science course, CSC 101, as the focus for our first prototype system. A preliminary set of interviews conducted with two groups of experts (educational theory experts and instructors of CSC 101), provided the foundation for our initial design decisions:

- course objectives, content and outcomes are the three main components to be addressed, and appropriate mappings among these three kinds of elements must be defined;
- Bloom's taxonomy provides one kind of hierarchical approach to the expression of the course objectives and/or the outcomes – therefore the tool should provide assistance in articulating the objectives/outcomes as well as in authoring the content in the context of those objectives/outcomes;
- the course design process should not be overly constrained by the taxonomy itself – this suggests that the agent should be functional in at least two modes: 1) explicit taxonomy, where the instructor wishes to do the course development in the context of the formal objectives and outcomes, or 2) transparent design, where the focus is on the content development, and the agent keeps track of objectives and outcomes “behind the scenes”.

With these ideas in mind, a metaphor of a “course design space” has been developed, which we define as the environment that contains all the resources an instructor needs to design a course. This environment includes electronic resources such as our software agent, content authoring tools, and the World Wide Web, as well as physical artifacts such as textbooks, videos, demonstration equipment, etc. The user interface of our agent reflects this notion of course design space by supporting asynchronous problem solving. Unlike the physical artifacts of the course design space, the agent is dynamic, in that it demonstrates how a change in one aspect of the design is reflected in other relevant components.

The presentation of this work in progress will include an overview of the design of the Bloom's Taxonomy agent, a demonstration from our first prototype, and preliminary results from our first round of functionality and usability testing.

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