

Conceptualizing Intelligent Agents for Teaching and Learning



Intelligent agents
perform tasks
for students and
instructors in
a dynamic, personal,
and smart teaching
and learning
environment

By **Ali Jafari**

Over the past few years, universities and colleges have made substantial progress in using the World Wide Web for teaching and learning and for distance-learning applications. Many schools have repurposed course offerings for distance learning, where students and instructors no longer have to meet in the same place at the same time. An increasing number of schools use course management software (CMS) to complement traditional classroom-based instruction. More recently, some universities — like Indiana University^{1,2} — offer a course template for all their courses.

While distance learning and the Web provide more convenient virtual access to learners around the world, some shortcomings limit the benefits, mainly from the perspectives of communication, collaboration, pedagogy, and course administration. The course instructor in a distance-learning situation, for instance, can no longer enjoy the powerful face-to-face communication channels available in a traditional classroom setting. The communication and collaboration channels are limited to capabilities of the tools available within the CMS.

The different brands of CMS range from homegrown software environments to sophisticated commercial products. Although new versions include easy-to-use Web authoring tools, most offer passive services. As a result, some instructors spend more time teaching a distance-learning course than teaching the same course in a classroom setting. This problem results mostly from the time-consuming operational nature of online courses. It is not unfair to call the typical CMS a “dumb software environment.” For instance, the instructor is expected to regularly check students’ progress by visiting many Web pages and using different tools within the CMS system to verify student progress and participation. This includes monitoring the message board activities log to verify student participation, consulting the drop box tool to see if students have submitted assignments, and regularly visiting the course activity log to monitor the magnitude of students’ online activities. Performing these tasks in addition to handling hundreds of e-mail messages has become a major time-consuming operation for most instructors. Intelligent agents functioning within a CMS system



or a campus portal could perform some of these tasks, relieving the instructor from manual monitoring and management of course activities.

Until recently, a major requirement of any CMS was ease of use. This no longer seems to be the main concern. We need smart learning environments that offer personal services with capabilities to learn, reason, have autonomy, and be totally dynamic. Using intelligent agents in a course-management environment can diminish some of the current limitations of CMS systems. For instance, once a course instructor logs into the course environment, a teaching assistant agent could provide information such as the names of students who have overdue assignments, have not collaborated in classroom message boards, have not taken an online quiz, or have not signed on for several days. Students' participation could even be ranked and categorized according to the instructor's preferences. The course instructor can configure an agent to give it autonomy to send personal

e-mail to those who have done better than average or worse than expected.

Intelligent Agents Defined

An intelligent agent is a set of independent software tools linked with other applications and databases running within one or several computer environments. The primary function of an intelligent agent is to help a user (client) better use, manage, and interact with a computer application such as a CMS or campus portal system.

Additionally, software agents, like human agents (for example, a secretary or an administrative assistant), can be authorized with the autonomy to make decisions and perform certain tasks. Agent-based technology systems are assumed to involve artificial intelligence (AI) and include a degree of autonomous problem-solving ability.³

Nicholas Negroponte⁴ talks about agents as perfect helpers, such as a "digital sister-in-law" that you ask for movie suggestions. Since she knows you and

your movie preferences and has extensive knowledge of new movies and movie reviews, she can intelligently advise you about which movie to see — an intelligent agent who is expert on both movies and you.

Students and Intelligent Agents

From a student perspective, a growing body of evidence indicates that the presence of intelligent agents is beneficial. Developing more human-like systems via intelligent agents makes users' interactions with the computer much smoother.⁵ Moreno and colleagues⁶ suggest that likable animated pedagogical agents may help students develop an emotional connection with the agent, facilitating their enjoyment of the learning situation. Along this line, the learner's development of a social relationship with a pedagogical agent is a key mechanism in fostering interaction and promoting learning within a computer-based learning system.⁷

In the MIMIC (Multiple Intelligent Mentors Instructing Collaboratively) research project at Florida State University, Amy Baylor^{8,9} consistently found that undergraduate students responded favorably to pedagogical agents, available to assist them in a Web-based learning environment. Specifically, participants found the agents to be useful, credible, and worthy of their attention, and they internalized the agents' suggestions.

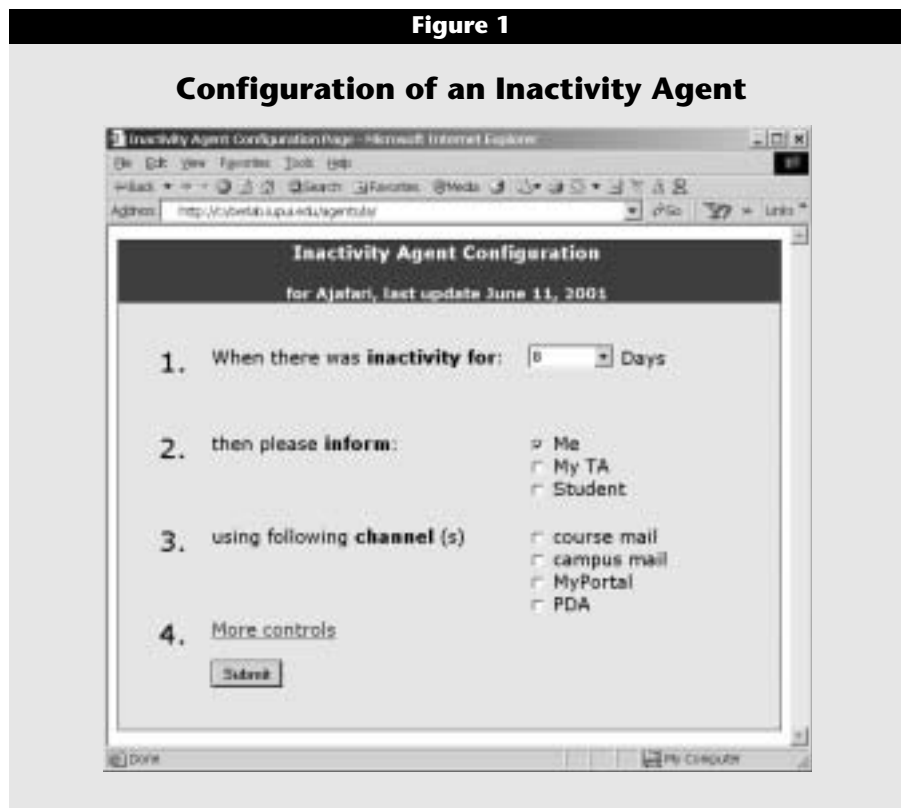
Need for Intelligent Agents

In order to expand the capabilities of CMS systems into an intelligent teaching and learning environment, I have suggested using a series of intelligent agents that perform teaching and learning tasks on behalf of teachers and learners. The proposed agents divide into three main categories or groups: Digital TA (teaching assistant), Digital Tutor, and Digital Secretary. Each group of agents is conceptualized to perform certain tasks normally carried out by a human being, such as TA, tutor, classmate, secretary, and the like. Each group may consist of one or more intelligent agents focusing on certain tasks within a course site, a series of courses, or the campus portal environment.

These agents may communicate with their human clients using a combination of text, graphics, speech, facial expression, and voice recognition. Besides using the Web browser on a PC, agents may use other types of communication environments including personal digital assistants (PDAs), telephones, instant messenger systems, and the like.

Digital TA Intelligent Agents

The intelligent agents acting as a Digital TA assist the teacher (instructor or other members of the teaching group) in various teaching functions often performed by a human teaching assistant or a graduate student. The Digital TA is a personal agent that may be configured by its owner, the human instructor. The concept is that the instructor will configure the Digital TA at the beginning of a course. This configuration could



include, for instance, the agent's level of autonomy to send overdue notices to students on behalf of the instructor and the language used in the body of the e-mail.

The Digital TA is more useful in distance-learning applications. For instance, in a typical distance-learning situation the instructor is physically isolated from the students, not necessarily knowing if and when students worked on an assignment, for how long, or what types of collaboration they used. The teacher remains mostly unaware of the student's progress until an exam or until the student submits an assignment or drops out of the course. In terms of student retention, the instructor ideally should be constantly and dynamically aware of a student's participation in a course and assist a discouraged student before he or she drops out. Additionally, the Digital TA can assist a course instructor with course operation and maintenance, similar to the assistance a human TA provides to an instructor.

Figure 1 suggests a simplified configuration procedure for programming a

Digital TA acting as an "inactivity agent." In this example, the agent is configured to send messages to the course instructor identifying students with more than one week of inactivity. The course instructor can further define the types and level of inactivity, such as lack of discussion on the class message board, failure to keep up with the reading assignments, or not taking quizzes. This is a very simple configuration of the agent.

In a more advanced procedure, the agent could continue monitoring student behavior after sending the initial notice to the student. An example of this might include sending an additional notice with stronger language if the student continues to ignore the first or second messages. Ultimately, the agent may notify the course instructor about a potentially troubled student. With this notification to the course instructor, the agent could provide additional background information about each troubled student, including past submission record, grades, class ranking, and so on. This amount of information empowers the instructor to take quick

and appropriate action for a troubled student.

As noted earlier, the Digital TA agents could include a series of agents, with only one being the inactivity agent illustrated in this example. The Cheat Buster intelligent agent described later is another useful example of an intelligent agent within the Digital TA group.

Digital Tutor

The intelligent agent acting as a Digital Tutor assists students with specific learning needs, just like a human tutor or a classmate. The Digital Tutor may act as a smart search engine, finding specific resources to solve learning needs for a student — an intelligent agent that is expert both on content and on understanding a student's learning needs. Depending on the level of its sophistication, the Digital Tutor could "learn" and become more expert and useful as it provides more assistance to a student and receives more feedback. Consider an online distance-learning course where a student has difficulties understanding new learning objectives. The Digital Tutor has access to outside mobile agents who can help to identify appropriate resources.

It is assumed that the Digital Tutor has access to students' learning profiles. Accessing student profiles and knowing students' strengths and weaknesses on a learning objective empowers the Digital Tutor to provide more useful resources. The student profile includes data dynamically collected from various databases, including campus information and registration databases (student information system, CMS databases, and so on); personal preferences entered by an individual student; and usage data dynamically obtained by monitoring students' online activities.

Examples of dynamic data obtained from various databases include the student's major and minor, previously taken courses, grades received for online quizzes, and final transcript information. A smarter Digital Tutor may use assessment data from passed courses to make suggestions on new learning modules and information resources. An example of this scenario might be a stu-

dent taking a second college English course who did very poorly in the grammar part of his first English course. Based on this data, the Digital Tutor might offer more learning exercises on grammar.

A Digital Tutor may also act as a communication agent. Consider situations where students within a course are working on an online project. The communication agent can dynamically show the list of online students within the CMS environment who are working on the same project at the same time. Students can use this list to establish a virtual online communication and collaboration session with other online students in the classroom. The course chat room, instant messenger, or whiteboard can support this purpose. A student could further program the communication agent to inform him or her when another student in the same class working on the same assignment signs onto the CMS environment.

Digital Secretary

The intelligent agent acting as a Digital Secretary assists students and instructors in various logistical and administrative assistant needs. Like a human secretary, the Digital Secretary performs tasks as directed by its supervisor — in this case, the human being at the keyboard.

A simple example of the type of tasks that a Digital Secretary might perform is the "out of office" e-mail notification offered by Microsoft Outlook. The owner of a calendar can program Outlook to send an automatic e-mail notification to those who send e-mail messages during a specific time period. The Digital Secretary, however, should offer more intelligent and sophisticated services than the out-of-office agent. Consider a situation where an instructor would like to send a different auto-response e-mail to only those students taking a specific undergraduate course or those in the course that meets in the evenings.

One major difference between a Digital Secretary and the other two groups of intelligent agents proposed in this article is the Digital Secretary's global functionality, distinct from the services

the Digital TA and Digital Tutor offer within specific courses. For instance, there might be only one group of Digital Secretary agents within a student portal, while there might be a series of dedicated Digital TAs offered for each course. With this concept, the Digital Secretary can be accessed within the faculty and student "MyPortal" environment, not within a course environment.

An account owner of portal or course management software will configure the Digital Secretary agent. Scheduling a meeting, finding a colleague with similar research interests, or finding the best math students who might serve as mentors are examples of tasks undertaken by a Digital Secretary in a teaching and learning environment. A Digital Secretary may also be used by other members of an educational institution who are not directly involved in teaching and learning, such as administrative staff, alumni, and parents.

Agents in Teaching and Learning Situations

Teaching and learning intelligent agents operate within CMS systems or campus portals. Each member of a CMS or campus portal (student, instructors, and others) has access to a series of personal intelligent agents after signing on. Users can configure their agents to perform specific tasks or services.

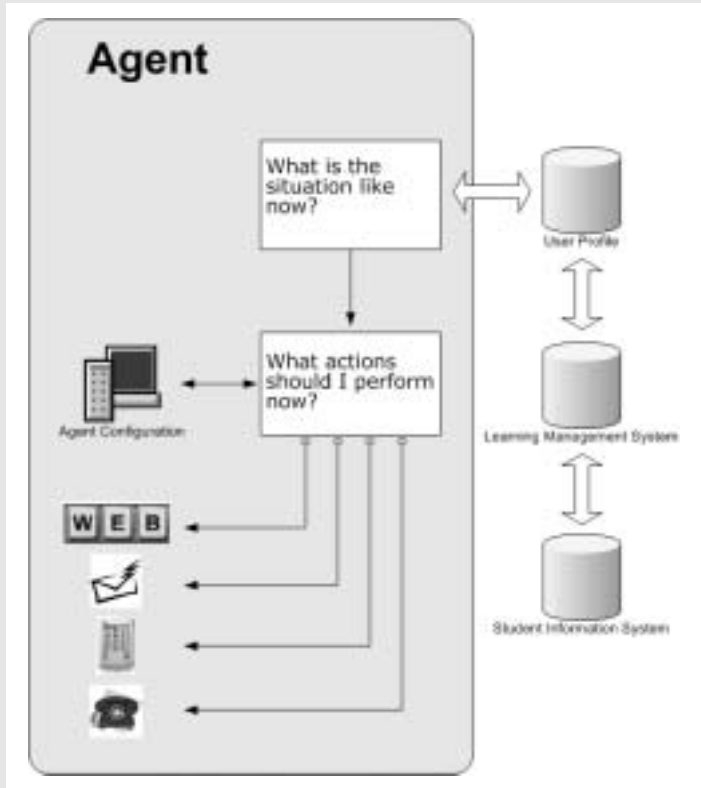
As illustrated in Figure 1, the owner can program the agent to sequentially monitor certain incidences, compare them with preset thresholds, and perform certain tasks on the owner's behalf. For instance, a teacher could program his or her agent to send e-mail notification to students with a grade lower than C who additionally did not participate in the classroom message forum for the previous two weeks.

Depending on the type of agent, the access for configuring them could be located in the "MyPortal" section of a campus portal or within a profile section of a CMS system. The agents could be multipurpose or course-specific (for example, an agent that monitors certain activities in Psychology 101).

Figure 2 illustrates the basic architecture of intelligent agents for teaching

Figure 2

Basic Agent Architecture for Teaching and Learning



and learning. As shown, an agent may have access to a variety of dynamic and static data, including data obtained from the campus student information system, course management system, and student profile databases. Based on this information and configuration settings provided by the owner of an agent, the agent can think and perform intelligent actions.

Given the massive amount of data processing involved, it might be necessary to run intelligent agent software on dedicated computer servers. Furthermore, various tasks performed by an agent could be distributed among several computer servers.

Incorporating Agents in Learning Management Systems

Who should develop and build intelligent agents? How can the agents be integrated into the CMS and campus portals? How much will future intelligent learning environments cost, and

what kind of resources and support will they require? These and other questions related to the design, development, integration, implementation, maintenance, and cost of intelligent learning environments will soon dominate the thinking of many technology administrators.

As discussed earlier, intelligent agents can be integrated into existing teaching and learning environments as an add-on tool. Alternatively, CMS and portal vendors may improve the functionalities of various tools within their learning management systems to offer similar intelligent services.

Consider the capabilities of the message board tool within the CMS system on your campus. The developer of the message board could release a newer version of its software that supports personalization and delivers user-defined functions, similar to the types of functions that external intelligent agents can perform.

Campuses with self-built course man-

agement and portal software will have more flexibility in the design and integration of intelligent agents. Since they developed their own code and maintain ownership and control of their software, the in-house development of agents could be accomplished faster and easier. However, this is only feasible for larger institutions with greater programming and database expertise, substantial resources within IT support units, or more research groups within academic departments of the institution.

Campuses that use off-the-shelf course management and portal software are at the mercy of their software providers to deliver intelligent learning tools. However, they might enjoy more cost-effective and plug-and-play situations. Additionally, integration and interoperability concerns are automatically resolved when integrating a vendor-designed agent into the learning management system developed by the same vendor.

Note that simple agents may not require a major development and implementation effort. For instance, the inactivity agent conceptualized in this article can be developed easily using a few lines of code to access and analyze data already existing within a relatively few tables of course management or portal databases.

Hardware and Software Issues

Like CMS systems, agent designs rely heavily on the use of databases. Agents use external databases to obtain information about each user and local databases to store the query results and to build user profiles.

Agents also use a substantial amount of computer resources on the database server side to run queries, stored procedures, triggers, and user-defined functions. Depending on the level of sophistication and intelligence, each agent may require its own server, operating system, and database software. This will certainly require budget provisions for purchasing new hardware and software, and for new maintenance and support services, especially in the area of database and

data storage. Agent use makes it easy to forecast more applications of databases in our institutions once we begin delivering intelligent learning management systems.

Learning Profiles

Intelligent agents such as the Digital Tutor agents rely heavily on learning profile data of individual learners. A learning profile collects data about a student's learning credentials, learning preferences, learning style, and learning habits.

Learning profiles include easily available data such as student grades and performance in various courses, along with learning objectives. They may include other data that could be used to suggest the appropriate learning style for an individual user. For instance, by analyzing a student's usage log and learning accomplishments, an agent could predict the category of learning style for that person. In addition, by analyzing learning profile data, an agent can intelligently suggest a pedagogical package suited for an individual learner.

Two major obstacles could inhibit the collection, analysis, and use of learning data in an educational institution. First, the technology and the software engine necessary for collection and analysis of learning data do not yet exist. Second, collecting and using learning data could create legal challenges for educational institutions. Universities should develop carefully considered, appropriate policies for the collection of student learning data. These obstacles might take several years to resolve, delaying the time when educational institutions can create a learning profile system to support an intelligent learning environment.

Intelligent Agent Scenarios

This article defines and conceptualizes the next generation of learning management systems using intelligent agents. A common method for defining new applications is by presenting them in realistic story formats or conceptual stories. The following conceptual scenarios illustrate the appli-

cations of intelligent agents in teaching and learning situations. The first scenario highlights the capabilities of an intelligent agent acting as a Digital TA assisting a university professor with various management aspects of her classes. The second scenario depicts the functionality of a Digital Tutor assisting a student with his learning needs. These scenarios also suggest a different communication and interface environment, not the keyboard-monitor communication model most commonly used today.

Digital TA Scenario

Monday morning, Professor Amy Baylor of Florida State University arrives at her office about 9:00 a.m. She teaches two courses that meet twice a week. The classes are complemented by course management software within the Florida State University campus portal environment.

Professor Baylor switches on her computer, logs on to her campus portal, clicks on the Digital TA icon, and begins organizing papers on her desk. A Digital TA named Angie appears as an animated character in the top right corner of her computer screen. "Good morning, Professor Baylor, here are the activities of your E214 and E723 courses. Over the past weekend there was moderate activity on your E214 course site."

Professor Baylor looks up from browsing through the campus newspaper. An XY graphic on her computer monitor shows the students' activities over the last three days with date and time indicated.

"Angie, next," says Professor Baylor, to see the next activity report.

"There are three students with overdue assignments," Angie notes. "Would you like me to send them your generic 'overdue assignment' e-mail notice?"

Professor Baylor, holding coffee in one hand and sorting books with the other, looks up and recognizes the pictures of the three students on the computer screen (see Figure 3). She asks the Digital TA to send generic e-mail messages reminding them about their over-

due assignment and the automatic deduction of ten points if they do not submit their assignment within the next two days. The Digital TA agent automatically sends e-mail to the students and marks the action in the course grade book.

Professor Baylor also notices that student Kandy Mills has missed deadlines for four out of five assignments during the course of this semester. She may want to talk to Kandy after her lecture on Friday (see Figure 3).

Tuesday, Professor Baylor gives an online quiz to her E214 class. On Wednesday morning, after she logs on to her campus portal, she receives a warning from the Cheat Buster intelligent agent: "Excuse me, Professor Baylor, I am noticing many similar quiz answers on Kandy Mills and Pat Warner's tests." The agent continues, "There is 92% similarity between right and wrong answers in their last quiz, and both took the quiz at the same time from two adjacent computer workstations in the university library."

The Cheat Buster intelligent agent then displays a three-dimensional graphic on the screen, highlighting similar answers. It also provides statistical analysis of the past six quizzes, highlighting similar answers. Professor Baylor sends e-mail messages to Kandy and Pat asking them to meet with her after class on Friday.

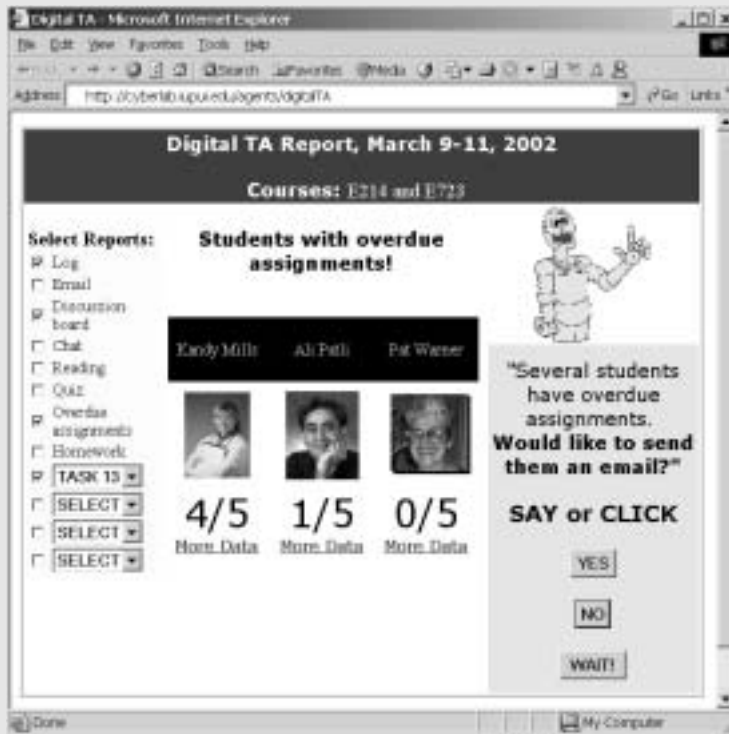
Digital Tutor Scenario

David Mills, a graduate student at Indiana University Purdue University Indianapolis, is writing a paper for his Social Psychology class. He would like to know students' opinions regarding the shooting at Columbine High School in Littleton, Colorado. He clicks on the Digital Tutor icon, enters some keyword phrases, and identifies his preferences for the type of tools and resources, such as threaded discussion boards, chat rooms, and Internet search engines.

The Digital Tutor (a mobile agent) will monitor all the course chatroom and message board activities and interrupt David when it observes any discussion regarding this matter. "Knock knock... Excuse me, Dave, there seems

Figure 3

Digital TA Displays Students with Overdue Assignments



to be a lot of discussion about the Littleton shooting in the Crime and Society course taught by Professor Amy Warner. Would you like me to take you to their chat room?"

The next Friday, after three days of vacation, David signs on to his CMS environment and logs on to the course. "Hi Dave, long time no see. You haven't logged on for three days, and you have several important notes to read, with two assignments due tomorrow evening," the Digital Tutor says. The Digital Tutor appears as an animated graphical display with voice synthesis and voice recognition capabilities.

Saturday afternoon David is working hard to finish his second due assignment. He is not quite clear about the scope of the assignment and whether he should identify the relationships among the tables in his database design project. He clicks on Intelligent Messenger to see if any of his classmates are currently online. After finding no students online, David con-

figures his Instant Messenger agent to inform him when one of his classmates signs on to the course.

David continues working on his assignment until interrupted by the Intelligent Messenger with the news that Cheryl Montana, his classmate in Database Design, has signed on to the course. In seconds, David is chatting with Cheryl and asking her about the database design assignment.

Conclusions

Current commercial learning management systems would benefit from the development of agent-based capabilities. The resulting intelligent learning management systems might use a variety of intelligent agents to offer dynamic — and smart — teaching and learning environments.

This article conceptualizes three types of intelligent agents to assist teachers and students: the Digital Teaching Assistant (TA), Digital Tutor, and Digital Secretary. Developing intelligent learning

management systems that incorporate these agents will offer some challenges, as well. Understanding these challenges and the emerging opportunities will help educational technology administrators prepare to take advantage of the next generation of teaching and learning environments. *e*

Endnotes

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