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The Journal of Technology, Learning, and Assessment

Volume 5, Number 3 · December 2006

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www.jtla.org

A publication of the Technology and Assessment Study Collaborative
Caroline A. & Peter S. Lynch School of Education, Boston College

Volume 5, Number 3

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Design: Thomas Hoffmann
Layout: Aimee Levy

JTLA is a free on-line journal, published by the Technology and Assessment Study Collaborative, Caroline A. & Peter S. Lynch School of Education, Boston College.

Preferred citation:

Abell, M. (2006). Individualizing learning using intelligent technology and universally designed curriculum. *Journal of Technology, Learning, and Assessment, 5*(3). Retrieved [date] from http://www.jtla.org.

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Abstract:

The American education system and its rigorous accountability and performance standards continually force educators to explore new ways to increase student achievement. The improvement in computer technology and intelligent computing systems may offer new tools for student learning and higher academic achievement. These systems have the potential to meet individual student learning needs using universally designed curricula and assessments. The purpose of this paper is to present a conceptual framework that harnesses the potential of intelligent learning systems, machine learning models, and universal design for learning principles to help formulate next generation instructional materials. By using intelligent and interactive curricula, educators could begin to move away from information disseminator into a facilitator of the learning experience.

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Individualizing Learning Using Intelligent Technology and Universally Designed Curriculum

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Introduction

On a national level, increased accountability standards continue to challenge educators to explore new methods to increase achievement. Cuban (1993) noted the reform efforts of the 1980s and 1990s sought to incorporate advanced technologies into schools to improve self-directed learning and active engagement. A significant goal for students is to become self-directed, thoughtful, and independent learners while educators make teaching and learning more productive. Efficiency and productivity are often subtly intertwined with reform efforts that look to maximize learning according to Chester (2002). However, efficiency and productivity though should not come at the cost of quality and academic rigor.

Meyer and Rose (2000) espouse the concept of Universal Design for Learning. Universal Design for Learning is a theoretical framework that guides the development of curricula that meets the needs of all students (Rose & Meyer, 2002). One component of this new paradigm focuses on the development of accessible interactive curriculum materials. These materials would engage the learner in new and empowering ways that align to their unique approach to learning. These learning materials can be altered and scaffolded based on learner needs and cognitive style. McKenzie (2000) defines instructional scaffolding as curriculum and instruction that contains six characteristics: 1) Provides clear direction and reduces students' confusion; 2) Clarifies purpose by helping students understand why they are doing the work and why it is important; 3) Keeps students on task by providing structure and clear pathways to learning. Students can make decisions about which path to choose or what things to explore along the path but they cannot wander off of the path, which is the designated task; 4) Clarifies expectations and incorporates assessment and feedback using models of exemplary work, rubrics, and superior student work samples; 5) Points students to worthy sources that reduce confusion, frustration, and time and offers them choices; and 6) Reduces uncertainty, surprise, and disappointment by offering multiple routes to success.

The new scaffolded materials leverage the power of technology blended with research based curriculum aligned to state and national education standards. Other examples of these interactive materials include curriculum units with embedded digital text, hyperlinked glossaries, concept maps, graphics, audio, video, and virtual reality. These materials would help meet broader student ability levels while engaging students based on their own approach to learning. The traditional printed textbook does not offer teachers and students the flexibility needed to meet diverse learning needs when compared to universally designed digital curriculum (Rose & Meyer, 2002). Behrmann (2001) advocates the use of instructional curriculum and materials in electronic format. The advantage to this approach is not the curriculum itself but rather the way the curriculum can be digitally displayed and altered through scaffolding and customization to meet the individual student's preferred approach to learning and unique ability level. When using digital versions of curriculum, students can display and engage the content in ways not possible with printed text. This would be beneficial in a larger intelligent learning system. Students would engage the learning process utilizing scaffolded audio, video, graphics, and text using personalized settings built into the curriculum which offers millions of potential learning variations. These digital versions could improve productivity and efficiency in schools, though more significant uses may be found in reducing barriers to learning and increasing personalization. Digital versions also reduce the cost and minimize the time consuming adaptations previously done by teachers. By placing the digital curriculum and accompanying tools such as text-reader software in the hands of students, educators give the controls to those who understand their approach to learning best: the students themselves. So how can researchers and curriculum developers begin to construct more intelligent and interactive curriculum materials?

A Model Guided by Learning Styles and Emerging Digital Media

Systems of any nature require grounding in appropriate theory and logic. Intelligent learning systems and accompanying digital media also require such grounding in the area of learning principles. Combined with the growth of digital media (e.g. streaming video, websites, audio, Blogs, etc.) students and teachers are now offered new types of information and learning resources that can be integrated directly into daily instructional activities leveraging computer and internet based technology.

Intelligent learning systems of the 21st century could provide students of all ability levels new ways to personalize and engage the learning process. This would avail students of the growing array of digital content now available. Learning resources have grown to include easy access to on demand streaming video in classrooms (United Streaming, 2005). Other resources include the growing availability of digital text from major publishers (Association of American Publishers, 2002), online assessments aligned to state accountability standards (Kentucky Department of Education, 2004), and informal teacher created assessments allowing immediate classroom feedback (Qwizdom®, 2004) which could be incorporated into intelligent learning systems. Assistance would be needed to guide students through a process that would create personalized learning profiles.

Currently, a major stumbling block is the lack of intelligent guides, also referred to as agents (Seaward, 1998), that can manage and coordinate the flow of learning materials based on unique student learning preferences. Bork (1997) noted the low quality of individualization in student learning and that computer-based learning systems do the same. He continues by encouraging more research on advanced algorithms leading to interactive computer environments that understand student needs. This understanding could result in highly interactive learning and improved engagement. A learning environment such as this should emulate the unique learning style of the individual student. Seaward (1998) explored the use of computer based digital assistants (e.g., icon or animation representing a participant) to facilitate learning. Specific analysis focused on the use of digital assistants built into Microsoft Word and Office. These assistants facilitated the improved utilization of the software by new users. Results revealed that fewer technical support calls were made once the assistants were introduced resulting in lower support costs. The assistants acted as a guide by asking questions and directing new users to the necessary features they were unable to locate. This same premise could be used by students as a way to interact with the curriculum. Students would preselect learning style preferences. Then the computer and accompanying databases would present interactive curriculum or learning material in the most opportune format for that student. These materials would all be built from the unique learning style of the student.

Importance of Unique Learning Styles

Baldwin and Sabry (2003) espouse the importance of learning style integration into interactive learning systems. Interactivity is important to adaptive learning systems. The interactivity allows students to engage their unique learning style based on intrinsic learning preferences. These preferences would help guide the intelligent learning system to individualize the curriculum and assessments to the individual student level. Baldwin and Sabry also expand on the importance of digital presentation methods found in interactive learning systems. These methods allow engagement across a wide variety of learning styles using multi-media (e.g., video, text, graphics, audio) technologies by allowing students to engage their strongest learning modality. Learning styles encompass a broad range of abilities and would be a vital component to the intelligent interactive curriculum. Felder (1993) presents a model of learning style dimensions that theoretically could be presented by a digital assistant (Seaward, 1998). The digital assistant would present various questions to determine the student's predominant learning style. This learning style assessment would represent the first component of an intelligent learning environment based on individual learning needs. This approach is not without inherent weaknesses though.

The challenge lies in what method the intelligent learning agent would use to initially process computational variables that are attributed to the way a person learns best. A simplistic method would use levels of shear cognitive or creative abilities determined by diagnostic tests. This would not allow for significant variability across individual's learning differences. It might also limit the dimension by which the human brain learns best and ways to categorize this. As a first step in the process, a learning style inventory could provide a more practical yet quantifiable measure (Table 1, next page). This information would then be transferred into intelligent learning systems and could serve as the foundational measure for complex algorithms that in the future would predict the most effective types of content presentation methods pertinent to the student's learning style. Nevertheless, learning style inventories have not held up flawlessly under the rigors of research (Atkinson, 1991, Duff, 2004) even though they may engage students and promote multidimensional learning experiences. Learning style inventories encompass a broad range of preferences and modalities. Some of these learning modalities are captured by Felder (1993) and aligned to student learning preferences and processing styles as seen in the following table.

Table 1: Learning-style Dimensions (modified from Felder, 1993)

Dimensions	**Categorization**	**Preferences**
Active–reflective	Information processing: through active and interactive engagement in physical activity or discussion.	Likes trying things, discussion, application of things learned. Difficulty attending to lectures.
Active–**reflective**	Information processing: through introspection	Prefers to think about what they learn quietly first. Prefer working alone. Difficulty sitting in lectures without chance to reflect on what has been learned.
Sensing–Intuitive	Perception of information: sights, sounds, physical sensation.	Tends to like learning facts, solving problems using familiar and well-established methods. Dislikes complications, surprises, to be tested on material that has not been fully covered in class. Tends to be patient with details and good at memorizing facts and doing hands-on (laboratory) work. Tends to be more practical and careful.
Sensing–**Intuitive**	Perception of information: memories, ideas, insights.	Likes innovation and prefers discovery-based approaches, finding relationships, dislikes repetition and impatient with details. Good at grasping new concepts and usually comfortable with abstractions and mathematical formulations. Tends to work faster. Gets bored with courses that involve a lot of memorization and rote learning
Visual–verbal	Perception of sensory information: pictures, diagrams, graphs, demonstration.	Tends to remember best what they see: static pictures (e.g. diagrams) or dynamic pictures (e.g. videos, DVDs).
Visual–**verbal**	Perception of sensory information: sounds, written, spoken words, formulas.	Tends to get more out of words (written and spoken explanations).
Sequential–global	Progress towards understanding: in logical and small incremental steps	Tends to gain understanding/find solutions in linear manner, with steps following each other logically. Sequential learners may not fully understand the material or establish a link with other parts, but able to know about specific aspects of a subject.
Sequential–**global**	Progress toward understanding: in non-linear way, large jumps, holistically	Tends to learn in large jumps, absorb material almost randomly, and may be able to solve complex problems quickly. Strongly global learners may be fuzzy about details or have serious difficulties understanding until they have the big picture.

The Digital Learning Environment

The interface, or look and feel an intelligent learning system has, is important to how a student or teacher will engage with it. Students and teachers may benefit from an interface where controls are easily understood, customizable based on student needs, easily accessible, and even available on-line. So what might such a system look like?

The actual interactive curriculum materials presented in a system to students is only one part of a broader digital learning environment though. The composition of the environment itself is very important. One can look at examples of rudimentary intelligent learning environments presented in various web-based formats. Current models center on the customization of user profiles exemplified by such websites as Amazon.com or My.yahoo.com. These interactive environments provide extensive customization features based on individual profiles and defined parameters set forth by the user. The differentiating factor between these sites and higher order intelligent learning systems is cognitive diagnosis and adaptive remediation (Shute & Psoka, 1994 & Psoka, 1994). Wasson (1997) outlined a number of important factors impacting advanced educational technologies that could influence the diagnosis and remediation of student learning needs. These factors include artificial intelligence (AI) routines involving planning, qualitative reasoning, plan recognition, expert systems, and knowledge representation and management. These components give the universally designed digital curriculum the ability to dynamically configure specific student centered instruction and remediation. In addition, a variety of student data (e.g. standardized and informal) could be ported into the system to provide various levels (low to high customization) of student centered content and feedback.

The environmental interface could be structured similar to an online portal with select components being downloadable. The interface would have extensive customization and intelligent learning features based on student learning preferences and instructional needs. A model of the discriminate levels of the system (Table 2, next page) adds further depth and customization to the intelligent learning system environment. This is accomplished by allowing district, building, and teacher level content to be added to the student's personal profile. This would then allow students to access state mandated content or assessment materials in a way that corresponds to the student's unique learning style while also meeting instructional goals. Researchers may consider the following framework for intelligent student learning environments that offer specific levels and interface components based on the educational organization's need.

Table 2: Intelligent Student Learning Environment Interface Levels

Access Levels	**Description**	**Components**
District	Content available from district level sources & programs. System managed as a district wide intelligent learning portal.	• System Administration Controls • E-learning components • Digital curriculum & assessment tools • Attendance records • File storage
School	Content is school specific targeting learning goals and outcome objectives.	• Licensed digital curricula • Online assessment system • School learning goals • School wide assessment results • Software tools & databases
Classroom	Classroom level instructional material identified, controlled, or created by teacher.	• Lesson plans • Online classroom assessments • Instructional content • Online resources • Intelligent learning & assessment tools • Student skills/interests inventories • Class grades
Student	Student created content including assignments, assessment results offering intelligent monitoring of curriculum progress, and test results.	• Productivity tools (word processors, spreadsheets, textreaders) • Databases • Student grades • Assignment and project files • Individualized digital curriculum • Email • Digital content controls (background color, text size, audio/visual features, content placement)

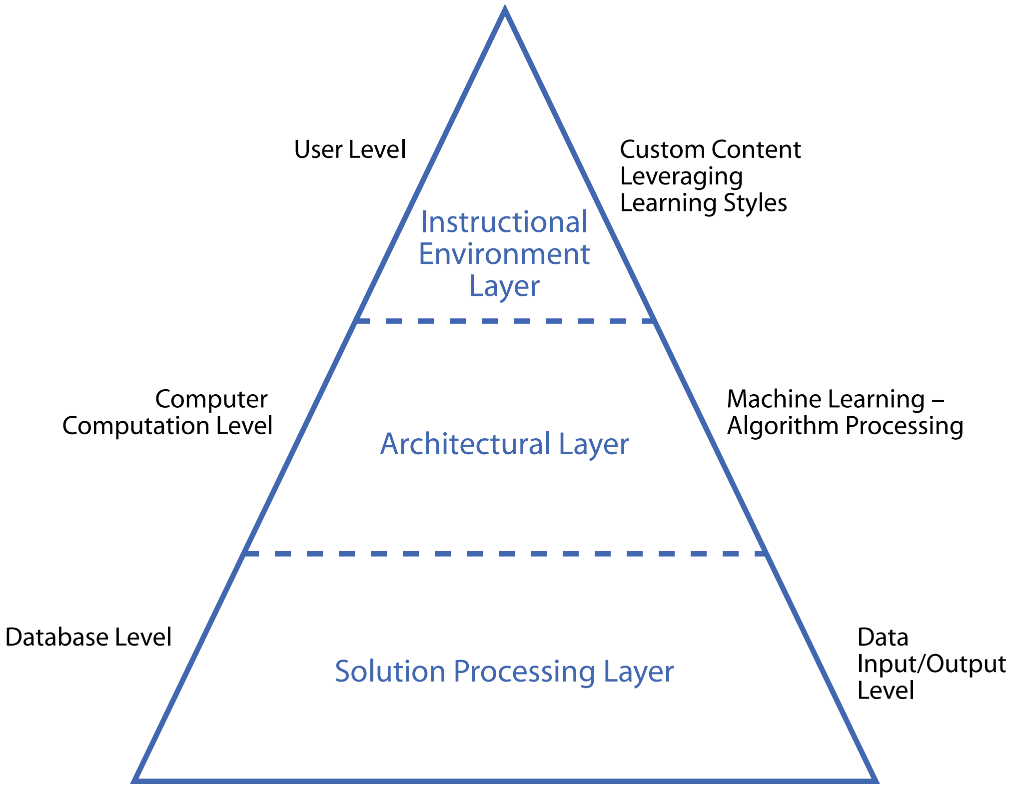
Intelligent student learning environments are linked inherently to the needs of the student and teacher and must not be forgotten. The interaction between the teacher and student plays a critical role in the learning process according to Wasson (1997). By developing intelligent learning tools (Emiliani & Stephanidis, 2005), the teacher could begin to move away from information disseminator to an information organizer and facilitator of the learning experience. More time would be dedicated to guiding, modeling, tutoring, and organizing material using intelligent computing as a tool for teachers and students. Intelligent computing could allow more dynamic learning in class and outside of the regular school day. By offering individualized interactive curriculum that is rigorous and aligned to state standards, more non-traditional learning sites could be offered in the community or home setting. Students who use an intelligent learning environment could utilize less powerful but portable handheld computers (Abell, Bauder, Simmons & Sharon, 2003) to access learning tools and the general curriculum away from school or when a computer isn't available. This would be accomplished through a consistent yet dynamically changing user environment.

Constructing the Environment

How would such an environment be constructed or customized? The environment would need to allow students and teachers access to the type of information (e.g. curriculum, learning tools and exemplars, etc) that meet their needs and cognitive level of students while challenging and guiding them through the learning process. Complex relational databases containing students' unique learning profiles (e.g. preferences) aligned to specific content level material would then begin to construct the learning environment and accompany activities.

The digital learning environment and accompanying interactive curriculum materials could be offered to students using complex algorithms to cull appropriate student specific content. This might be offered to students through an online portal with accompanying wireless connectivity or through synchronization of curricula presented using portable handheld devices. The interface of the online portal would offer extensive customization and intelligent learning features. These features would be based on student and teacher needs. Students would interact with the content for class assignments or discovery learning which in turn would trigger algorithms processing through agents to relational databases resulting in individualized student specific content. The content would be presented in the students' preferred learning style while the learning system also intelligently adjusts content levels and supports. Wu and Lee (1998) advocate a more concise approach to the development of intelligent learning systems. They outline a model that includes: a) a systems approach to intelligent learning systems; b) a paradigm hierarchy; and c) the emergence of an agent model capable of initiating action. The computational hierarchical layers Wu and Lee (1998) elaborate on include three levels (Figure 1, next page). The first is an instruction-interaction layer which is at the top and addresses problems by treating them in a logical manner. All problems are defined by the instructional tasks needing action. The second level is the architectural layer. This middle layer acts as a conduit between the instructional-environment layer and the lower level processing layer. Architectural layer components include the capabilities and performance characteristics of the aggregated functional components of entities in the lower processing level interconnected with the instructional-interaction layer. The third level is the processing layer. This layer is the lowest level where detailed interoperations and processing components are performed. This processing results in intelligent system output based on unique student parameters (e.g., learning profile characteristics).

Figure 1: Intelligent Learning System Layers



Intelligent learning systems depend heavily on well planned and integrated systems that adjust and adapt to the learner's needs which are guided by learning goals. Consideration should be given to the standardization of instructional content at the meta level. This standardization would utilize tagging or markup language that would allow databases to quickly analyze and process information requests from students while recognizing their unique learning styles and preferences. This processing would depend on access to appropriately tagged digital content which agents could then process, parse, and display relevant instructional content. The National Instructional Materials Accessibility Standard (NIMAS) (CAST, 2005) presents the first nationally recognized standard for digital content creation and markup. NIMAS will help guide the digitization of accessible instructional materials by publishers in a systematic and hierarchical manner organized around the individual document meta-information. This structure works from the highest level container of a book's major divisions down to the furthest subdivisions that nest within chapters and includes information supplementary to the main text and narrative flow (CAST, 2005). The NIMAS format is a significant step forward on the road to intelligent learning systems but is only one of many necessary components.

Another model is advocated by Amigoni, Gatti, Pinciroli, and Roveri (2005). They advocate the utilization of a distributed hierarchical task network that combines both centralized and distributed features from which information can be accessed. This would allow centralized processes to access closed networks. The processes or agents would distribute licensed copyrighted content, state specific curriculum, or assessment materials while working within predefined, approved user parameters such as learning style preferences, grade levels, and even content specific information. Distributed features could allow specific content to be accessed from wider less stringent or controlled sources such as public websites, government databases, and select media services.

Assessment Systems

The same parameters for intelligent learning systems and content structure are critical and warrant integration with accessible assessment systems. Agents would process and respond to student input resulting in assessment results parsed from structured or informal assessment content using a NIMAS like schema to catalogue and store student test content. Agents would also direct the storage of assessment results and preferences. Research in the area of accessible assessment (Abell, Bauder & Simmons, 2004; Abell & Lewis 2005; Dolan et, al., 2005) advocates the same importance be placed on universally designed online assessment methods which benefit and guide the instruction of all students regardless of ability level. The researchers explore the flexibility within the assessment environment resulting from the use of digital content (e.g. text, video, audio, or combinations of). Flexible content representation offers more opportunities to connect with individual student learning styles, thereby increasing knowledge transfer. Quellmalz and Kozma (2003) support the use of information and communication technologies (ICT) to help students solve complex problems. The ICTs such as simulation, visualization, modeling tools, web connectivity, and online communication allow learners to engage with the assessment process in new and naturalistic ways. These tools along with universally designed assessment materials could be incorporated into the instructional environment layer leveraging machine learning models. Models such as Latent Semantic Analysis (LSA) utilize human scored essays as a vector triggering continuous computational analysis of the similarity between each to-be-scored essay and each of the previously scored essays (Landauer, Laham, & Foltz, 2003). LSA does not depend solely on direct prediction which is based only on intuitive judgments from a predefined set of index variables. As the field of intelligent computing develops and matures, various forms of machine learning models emphasizing categorization such as Naive Bayes (Tzeras & Hartmann 1993), Rocchio (Rocchio 1971), *k*-nearest neighbors (Yang 1994), and decision trees (Quinlan

1986) warrant consideration and further research. Baker (2003) encourages the field to adopt models for technology design and assessment that would include a set of minimum features: 1) linkage to cognitive demands or requirements (e.g. problem solving, verbal comprehension); 2) methods for attributing validity for various assessment purposes; 3) procedures for generating multiple instances of a task, item, or simulation; 4) analytic approaches for providing reports targeted to users; 5) quality control routines to assure content quality, appropriateness to the learner; and 6) fairness. More also needs to be done to help teachers see value in this type of assessment model.

Stiggins (2004) postulates that educators have inherited an assessment legacy that actually prevents teachers from tapping the full power of assessment for school improvement. Maximum learning comes from active engagement between the teacher and student. This engagement allows students to decide if they are likely to succeed, if meeting the standards is worth the effort, and finally the results of possible failure. Students look at these factors on a personal level. Stiggins (2004) further alludes that instructional decisions, in addition to being personal, also occurs in a fluid day to day instructional environment, not once a year resulting in standardized test scores. Using online assessment tools allows teachers and students to quickly and efficiently assess individual learning and class wide instructional progress. Future scenarios could see paper and pencil quizzes replaced with online or personal digital assistant (PDA) based quizzes that students could take during class or on their own time at home. Online access, PDA, or digital ink devices (Economist, 2000) would offer a variety of options for students to take and review assessment results. Other interactive assessment methods using interactive class feedback (Qwizdom, 2004) could be used which depend less on online connectivity while still tracking results at the student and classroom level for teachers and students to analyze.

Technology Infrastructure and Interactive Media Challenges

To have a viable intelligent learning system, students and teachers require easy access to technology and digital content that is aligned to the curriculum. The intelligent learning system is intimately connected to universally-designed instructional content offered in digital format that includes the technology needed by students to display and interact with it.

The technology infrastructure currently available in today's society including schools continues to grow and will be a benefit to intelligent curricular applications. This growth is in part due to the growth of the internet and free wireless network access. The necessary components of intelligent learning curricula are currently available or becoming available. These include robust computer networks and storage capabilities, wireless network access, affordable computers and handheld display devices such as cell phones or Palm Pilots to display digital content, inexpensive broadband Internet access, national file format standardizations such as NIMAS, and textbook publishers offering materials in digital formats. More work is required to shape these components into model intelligent learning system applications.

A number of components necessary for intelligent learning curricula need research and development efforts to move forward. These areas include the textbook publishing industry continuing to move toward digital content production and sale using market driven pay for fee models while adopting file format standardizations such as NIMAS. The national file format standardization found in NIMAS allows researchers to delve deeper into ways that digital content can be personalized using different tag structures. Personalization of the learning environment also comes with risks and criticisms though.

Clark (1983) noted that technology or "media" is not the driving force behind learning; it is the content that is presented through the media itself. Research in the use of technology in education is ambiguous and falls on both sides of the debate. This is supported by the research of MacArthur, Ferretti, Okolo, and Cavalier (2001) who conducted an extensive review of educational technology research. Their review of evolving technology applications used for students with literacy problems found that select students benefited while others did not. This hastens the point that technology may be more beneficial when used in the context of a student's unique needs rather than universally.

Individual student needs are often varied and significant. This raises the point of how much control and flexibility of the curricula should be given to students in an effort to help them achieve at high levels. Too much flexibility and control of content in the hands of students could have an unintended effect of lowering expectation and student challenge. Close monitoring by teachers, instructors, or learning coaches may need to be instituted to allow students the appropriate challenges needed in the learning process itself.

Future Research and Next Steps

Advanced research is needed to construct models that probe, analyze, and predict student learning needs. This research should take into account current student data such as ability level, interests, standardized and non-standardized test results, as well as personal learning goals and profiles. One way to assemble intelligent learning curricula may be to align individual student learning characteristics with tagged instructional content using pedagogical tags rather than purely structural tags which would not take into account the students learning characteristics.

To integrate more intelligent technology with learning processes, linkages are also needed between learning and cognitive scientists along with computer and computational researchers. Great strides can be made through better understanding of cognitive learning styles and how to align these to intelligent computing to create custom learning environments and materials for all students. The blending of intelligent computing with learning style preferences and the subsequent schema could provide the conceptual models needed to build more advanced and personalized learning systems.

Research might also examine the coordination and execution of algorithms that create learning style specific environments for individual learners perhaps using pedagogically tagged content. This would allow computer databases to analyze and process student requests and create instructionally relevant curriculum material aligned to state standards and student learning styles. This research should focus on a description of the environment, goals, and student capabilities in the form of possible learning profiles. Lastly, flexible computer models that allow for a variety of learning styles to be met through intelligent learning systems should be explored.

Though numerous challenges lay ahead in developing intelligent interactive learning systems and accompanying curricula, the potential benefits to society warrant the physical, intellectual, and financial investment. This investment in the development of intelligent learning systems has the potential to impact every individual regardless of ability by opening new doors to learning and potentially a better life.

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