Adaptive Learning Bibliography

Prepared by Kate Ford, Center for Innovation in Learning
Last updated 12/12/2013
Cited by numbers (via Google Scholar) current as of 12/12/2013

Literature Reviews/State of the Art Papers

Akbulut, Y. & Cardak, C. S. (2012). Adaptive educational hypermedia accommodating learning styles: A content analysis of publications from 2000 to 2011. *Computers & Education, 58*(2), 835–842. Elsevier. http://dx.doi.org/10.1016/j.compedu.2011.10.008
Cited by 20

The authors reviewed 70 recent studies focused on adaptive systems and content intended to address individual student differences. The authors differentiated between adaptivity as a programming intervention and adaptability as a learner-controlled modification to one of the provided parameters of the instruction. Learner control was observed in 23 of the models. The majority of the studies reviewed covered learning-style based adaptivity, with the rest addressing student modeling. According to the authors, Felder-Silverman's Learning Style Dimensions was used most, followed by cognitive styles, Kolb, VARK, and others. Data sources for the dynamic student modeling used in 28 of the studies included student behaviors, test scores, and students' indication of learning goals or preferences. However, the use of multiple data sources for modeling was seen in only seven of the studies. Some studies suggested that the proposed models impacted student satisfaction and success, but the authors observed that the findings on specific learning outcomes were generally lacking. They concluded with several suggestions, including increasing the level of rigor in the research and increasing the level of collaboration between researchers from the computer sciences, instructional design, educational technology domains.

Brusilovsky, P. & Peylo, C. (2003). Adaptive and intelligent web-based educational systems. *International Journal of Artificial Intelligence in Education, 13*(2), 159–172. IOS Press. Retrieved from: http://www2.sis.pitt.edu/~peterb/papers/AIWBES.pdf
Cited by: 500

In this update to Brusilovsky's 1999 review, the authors described recent advances in the design model for adaptive and intelligent web-based educational systems. Brusilovsky categorized systems that model students' learning goals, preferences, and existing knowledge as adaptive and those that use artificial intelligence to perform the role of the instructor in tutoring and correcting as intelligent. Systems can be one or the other, or combine elements of both. The authors updated Brusilovsky's original classification categories to include three subcategories of Web systems: *Adaptive Information Filtering*, including content or collaborative filtering technologies; Intelligent *Class Monitoring*; and *Intelligent Collaboration Support*, including adaptive group formation and peer help technologies. Other optimal path technologies representing the current state of the art (at the time of publication) in curriculum sequencing and intelligent tutoring technologies, including intelligent solution analysis and problem solving support were described along with sample systems in each category. The authors also discussed changes in the design paradigm driven by growth in Web-based education.

Brusilovsky, P. (2004, September). Adaptive educational hypermedia: From generation to generation. In *Proceedings of 4th Hellenic Conference on Information and Communication Technologies in Education*, Athens, Greece (pp. 19-33). Retrieved from: http://www.sis.pitt.edu/~peterb/papers/PB_ETPE_04.pdf
Cited by 48

Prepared by Kate Ford, Center for Innovation in Learning
Last updated 12/12/2013
Cited by numbers (via Google Scholar) current as of 12/12/2013

This article defined adaptive hypermedia systems as systems that personalize the learning experience of the user, based on their preferences and knowledge. The author provided a historical overview of the development of the adaptive hypermedia systems with the first generation being traced back to the early 1990s. Brusilovsky describe the first generation of adaptive educational hypermedia systems as occurring between 1990 and 1996. Two fields, intelligent tutoring systems (ITS), and educational hypermedia, emerged during this time. The second generation commenced in 1996, with the majority of published papers focusing on Web-based adaptive hypermedia systems. Brusilovsky suggested that third generation systems based on interoperability, standards, and reusability of content would replace LMS systems such as Blackboard and WebCT. With the maturation of the third generation, Brusilovsky predicted increased integration of adaptive technologies into the process of everyday Web-enhanced learning.

Di Bitonto, P., Roselli, T., Rossano, V. & Sinatra, M. (2013). Adaptive E-Learning environments: Research dimensions and technological approaches. *International Journal of Distance Education Technologies (IJDET), 11*(3), 1–11. IGI Global. http://dx.doi.org/10.4018/jdet.2013070101
Not yet cited

The authors explored various adaptive learning solutions, with the goal of diagnosing the strengths and weaknesses of each. The authors indicated that the three approaches that had propelled the e-learning research forward and aided in facilitating technological solutions for improved distance learning were: multi-agent system, adaptive SVORN package, and an e-learning recommender system.

Education Growth Advisors. (2013). *Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education*. Stamford, CT: Education Growth Advisors. Retrieved from: http://edgrowthadvisors.com/research/
Not yet cited

This report described adaptive learning as the technology and data driven customization of an individual pathways through the content of a course and highlighted the potential of adaptive learning to increase retention, provide better measures of student learning, and improve pedagogy and learning outcomes. The report categorized potential suppliers/partners according to whether they provided adaptive platforms and authoring tools or technology-driven adaptive learning content. When choosing vendors/suppliers, university leaders were advised to determine whether their institutional goals were to "tweak" or "transform," as the latter will likely require both platform and publisher solutions. A list of providers, organized according to business model (publisher or platform) and instructional model (supplemental or whole course) was provided. The report indicated that the most sophisticated offerings dynamically draw from multiple sources of student data to inform adaptive delivery along one or more dimensions, such as content sequencing, modality, duration, frequency and timing, and alignment with individual student knowledge, learning style, pace, ability and motivation. These offering may also provide varying degrees of learner and instructor control over the "adaptive" delivery options afforded. The authors indicated that institutions can expect to make a reasonable investment of time analyzing possible solutions, given the current maturity level of the adaptive solutions marketplace. Also, those involved in instructional design, including subject matter experts must be able to collaborate effectively with

solution providers for the full potential of adaptive learning to be realized at scale. While additional rigorous experimentation is recommended, the report also provides several preliminary results:

- An 18% increase in pass rates and 47% drop in withdrawals in mastery-based math courses attributed to Arizona State University's partnership with Knewton.
- A 7% average increase in course pass rates among 700 university and community college students using McGraw-Hill Education's LearnSmart versus textbook test bank questions.
- 25% faster completion rate with comparable performance for students participating in a randomized controlled study involving the use of Open Learning Initiative's introductory statistics course (versus the face-to-face course).

Education Growth Advisors. (2013). *Learning to Adapt: Undestanding the Adaptive Learning Supplier Landscape*. Stamford, CT: Education Growth Advisors. Retrieved from: http://edgrowthadvisors.com/research/
Not yet cited

Expanding on their March 2013 report, "Learning to Adapt: A Case for Accelerating Adaptive Learning in Higher Education," the authors suggested in this report that higher education administrators begin looking now at the increased number of supplier offerings in the emerging market for adaptive learning systems. To assist university decision makers, the authors profiled eight suppliers of a range of adaptive learning solutions. Rather than attempt to rate or rank-order these suppliers, the report instead examined the providers from the perspectives of how their offerings utilize adaptivity for personalized learning, the product offerings and attributes relative to instructional considerations, and most importantly in terms of scalability, the maturity level of the solutions offered.

Jarrett, J. (2012, April). Bigfoot, goldilocks, and moonshots: A report from the frontiers of personalized learning. *Educause Review Online*. Retrieved from: http://www.educause.edu/ero/article/bigfoot-goldilocks-and-moonshots-report-frontiers-personalized-learning
Not yet cited

In this thought leader article, Jarrett used Bigfoot, Goldilocks, and Moonshots as metaphors to describe innovation "sightings" of previously elusive improved learning outcomes at lower costs, customized learning pathways fitted to the individual student, and transformational programs with design, delivery, and cost structures that represent a marked departure from the status quo. Examples of innovations labeled as "bigfoots" included the intelligent/adaptive tutoring learning content developed through Carnegie Mellon's Open Learning Initiative (http://oli.cum.edu), which promises to free faculty time for higher-order learning that cannot yet be delivered via intelligent tutors. NCAT's *Changing the Equation Initiative* is another example provided, in which 32 two-year colleges redeveloped developmental math using the NCAT *Emporium Model* and commercially available adaptive learning software to reduce instructional costs by 20%. Open course repositories, such as Monterey Institute for Technology's NROC, offering free, high quality content were also labeled as bigfoots, as was Arizona State University's partnership with Knewton to provide customized developmental math content for 5,000 students, which was credited with reducing

semester drop rates, increasing pass rates, and enabling students to complete their courses up to four weeks early.

"Just right" Goldilocks examples included Arizona State University's degree pathways program, which was credited with boosting the number of "on track" students from 22% to 91% and increasing first-year retention by 8 percent in just three years. Moonshots, according to Jarrett, aimed to provide "high-quality affordable education" at scale. Institutions pursuing moonshots adopted new education models and pedagogical approaches informed by learning science and enabled by technology advances to introduce competency rather than credit based degree programs that promise faster completion. These breakthrough models typically employ some combination of prior learning assessment, adaptive learning, peer-to-peer learning, learning analytics and/or elements of gamification, such as badges. According to Jarrett, Bigfoots, Goldilocks, and Moonshots challenge what has been called the "iron triangle" of higher education -- cost, quality, and access, in which attempts to improve one angle have typically come at the expense of another angle.

Magnisalis, I., Demetriadis, S., & Karakostas, A. (2011). Adaptive and intelligent systems for collaborative learning support: A review of the field. Learning Technologies, *IEEE Transactions on*, *4*(1), 5-20. Retrieved from: http://www.computer.org/csdl/trans/lt/2011/01/tlt2011010005.html
Cited by 27

In a structured review of the recent literature (n=105 articles), the authors examined design issues and learning impact of adaptive technology for "collaborative learning support systems" (AICLS). Based on a comparative review, they proposed that the following categories for classifying and analyzing AICLS systems: instructional objectives; adaptation targets; modeling; technology; and design. The authors differentiated between adaptive systems, which present content or provide navigational support tailored to individual learning styles and needs, and intelligent tutoring systems, which rely on artificial intelligence and modeling of domain-specific problem solving, noting that the recent research trend involves bringing together the attributes of these systems within the context of collaborative computer-supported collaborative learning (CSCL). The authors found that artificial intelligence and social media techniques are increasingly being used in AICLS for interventions, peer interactions, and other domain specific learning activities. Based on the evaluation data provided in the articles, the authors concluded that the intervention afforded by adaptive and unobtrusive systems may result in improved motivation, subject area knowledge, and collaboration skills for learners.

Mulwa, C., Lawless, S., Sharp, M., Arnedillo-Sanchez, I., & Wade, V. (2010, October). Adaptive educational hypermedia systems in technology enhanced learning: A literature review. In *Proceedings of the 2010 ACM conference on Information technology education* (pp. 73-84). ACM. http://dx.doi.org/10.1145/1867651.1867672
Cited by 22

The authors summarized that Adaptive Educational Hypermedia Systems (AEHS) were able to incorporate student learning styles and preferences into the learning environment to make the learning process more efficient in accordance with student knowledge and abilities. They suggested that investing time and effort to integrate an AEHS systems into teaching plans was worthwhile,

since incorporating student centered learning styles into AEHS afforded a more personalized and effective learning experience with improvements in learner satisfaction and knowledge gain. The authors also found that the real advantage and benefit of AEHS systems was the ability to dynamically personalize content and the navigation based on multiple factors.

Zliobaite, I., Bifet, A., Gaber, M., Gabrys, B., Gama, J., Minku, L. & Musial, K. (2012). Next challenges for adaptive learning systems. ACM SIGKDD *Explorations Newsletter, 14*(1), 48–55. ACM. Retrieved from: http://sigkdd.org/sites/default/files/issues/14-1-2012-06/V14-01-07-Zliobaite.pdf
Cited by 4

In this article, the authors compared and contrasted traditional machine learning with adaptive learning and described how the increasing availability of massive amounts of real-time data, computational resources, and user needs impact the design of adapting learning (predictive systems), which include recommender and decision support systems. The authors suggested that additional research is needed to close the gap between adaptive learning technology and application needs in a variety of settings. Key challenges identified included scalability, real-time streaming data, and system transparency, and usability/user interface, particularly with regards to the level of human intervention needed for tuning and setting parameters. Additional challenges included effectively addressing and balancing the need for expert knowledge integration and self-adapting algorithms and fully automated model building encompassing data preparation and feedback.

Metadata Standards and Ontology Design

Burgos, D., Tattersall, C. & Koper, R. (2006). *Representing adaptive eLearning strategies in IMS learning design*. Retrieved from http://hdl.handle.net/1820/601
Cited by 56

The authors provided an overview of the major types of adaptive learning seen in online learning and described how IMS Learning Design Specification (IMS LD)-modeled learning can effectively address learner-centric needs pertaining to content, time, presentation order, assessment, interface, etc., within personalized learning solutions. According to the authors, modern adaptive systems provided for four key approaches to personalized learning based on student learning goals (macro-adaptive), adjusting the type of instruction or media used to the needs or preferences of the student (aptitude-treatment interaction), adapting based on learning behavior of students obtained through clickstream data, and social learning (constructivist-collaborative). The specific adaptations addressed user interface (navigation/usability), content order, or type or contents of materials presented. Other types of adaptive learning support included problem solving support, information filtering, collaborative grouping of students, adaptive testing, and real-time course modifications by the instructor to meet the specific needs of learners. The authors described the level of support IMS LD provides for each of these areas, with a primary focus on environment and method, versus roles and activities. They suggested where learning activities can be linked to external tools, that the IMS LD serve as a container. They also summarized the state of the art in IMS LD editors as a "complex process," requiring in-depth knowledge of the IMS specification and of the various IMS LD editors.

Prepared by Kate Ford, Center for Innovation in Learning
Last updated 12/12/2013
Cited by numbers (via Google Scholar) current as of 12/12/2013

Chung, H.-S. & Kim, J.-M. (2012). Ontology design for creating adaptive learning path in e-learning environment. In *Proceedings of the International MultiConference of Engineers and Computer Scientists* (Vol. 1, pp. 585–588). Retrieved from http://www.iaeng.org/publication/IMECS2012/IMECS2012_pp585-588.pdf
Cited by 4

The authors classified applications of ontology technology to the education arena into three major categories: Syllabus-based ontology; Learning object-based ontology; and Content retrieval ontology. The authors introduced a subject ontology model that included the creation, integration and interfacing of multiple student-driven ontologies in order to enhance the student learning experience. They found that the application of the subject ontology model to a class resulted in enhanced learning outcomes.

Essalmi, F., Jemni Ben Ayed, L. & Jemni, M. (2010). An ontology based approach for selection of appropriate E-learning personalization strategy. *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on* (pp. 724–725). http://dx.doi.org/10.1109/ICALT.2010.209
Cited by 3

This paper discussed personalization strategies and how to select the most appropriate strategy based on course specifics and the individual preferences. An ontology entitled OSPS (Ontologies to determine Significant Personalization Strategies) was proposed by the authors to help personalize the course and generate appropriate learning scenarios. Based on their case study findings in a programming course, the authors indicated that OSPS allows for useful analysis of metadata and correlates it to users' personalization preferences. A follow-up study was planned with additional learning objects involving several courses.

Hampson, C., Conlan, O. & Wade, V. (2011). Challenges in locating content and services for adaptive elearning courses. In *Advanced Learning Technologies (ICALT), 2011 11th IEEE International Conference on* (pp. 157–159). http://dx.doi.org/10.1109/ICALT.2011.52
Cited by 2

This paper described the many challenges in locating learning content materials and Web-based services for personalized online course delivery. One of the key challenges encountered was providing the technology resources to facilitate dynamic service adaptation techniques yielding more adaptive, personalized, and efficient student learning experiences. The authors also discussed the existing adaptive engine structures that teachers can use to create an adaptive course. A case study was also provided with various scenarios detailing the infrastructure support in the adaptive learning process.

Piedra, N., Chicaiza, J., López, J., Tovar, E. & Martinez, O. (2010). Design study of OER-CC ontology-A semantic web approach to describe open educational resources. *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on* (pp. 207–209). http://dx.doi.org/10.1109/ICALT.2010.64
Cited by 1

The authors explored uses of a semantic paradigm model in Open Educational Resources (OERs). A description of OERS and Creative Commons (CC) resources was provided. An OER-CC ontology was developed by the authors to infer knowledge and to extract pertinent information as a proof of concept for facilitating sharing and accessibility of existing digital content. The authors posited that the data integration and accessibility provided by the ontology will allow more tasks to be performed more autonomously and effectively. Additionally, by implementing different rules and axioms of the OER-CC ontology, the authors identified inconsistencies contained in the learning material and the impact on the intended use of the material.

Rezgui, K., Mhiri, H. & Ghedira, K. (2012). Competency models: A review of initiatives. *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 141–142). http://dx.doi.org/10.1109/ICALT.2012.128
Cited by 1

The authors provided an analysis of the competency model concept and its various forms and dimensions. They explored current metadata standards and how ontology helps conceptualize data into retrievable categories of knowledge. Because existing data, such as title and description, are not readily formatted to facilitate machine accessibility, the authors concluded that new standards and knowledge must be introduced to facilitate retrieval of relevant data that will build upon the competency relationships.

Szilagyi, I. & Roxin, I. (2012). Learner Ontology for the Active Semantic Learning System. *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 393–394). http://dx.doi.org/10.1109/ICALT.2012.162
Cited by 1

The authors discussed an active semantic learning system that could infer characteristics for an individual learner. Using ontologies enabled the system to categorize, understand and interpret a profile of an individual learner. Based on the dimensions of the learner and the relation to other objects, the learning system provided a more efficient and adaptive learning experience. The authors found that students' learning experience was positively impacted by the capability of the learning system to facilitate learning interactions best suited to the individual learning style and individual learning preferences.

Optimal Learning Path Strategies For Adaptive Content Delivery/Navigational Support

Alkhuraiji, S., Cheetham, B. & Bamasak, O. (2011). Dynamic adaptive mechanism in learning management system based on learning styles. *Advanced Learning Technologies (ICALT), 2011 11th IEEE International Conference on* (pp. 215–217). http://dx.doi.org/10.1109/ICALT.2011.69
Cited by 2

In this conference paper, the authors discussed incorporating adaptivity into the way information was presented to students based on individual learning styles and preferences. A Baysian network was used to determine preferred learning style. Static and dynamic approaches were examined. Dynamic adaptivity, which enabled modifications to a student's profile over time was preferred. The authors

concluded that further research was needed to investigate the varying styles of presentation and to move towards a more dynamic adaptive learning environment.

Bargel, B. A., Schröck, J., Szentes, D. & Roller, W. (2012). Using learning maps for visualization of adaptive learning path components. *International Journal of Computer Information Systems and Industrial Management Applications, 4*(1), 228–235. Retrieved from http://www.mirlabs.org/ijcisim/regular_papers_2012/Paper25.pdf
Cited by 4

The authors described most e-learning courses as linear representations, supplemented by additional reading materials and completion of evaluative quizzes, whereas, adaptive learning systems were constructed of individual learning paths geared towards personalized learning to match the students' learning styles and preferences. The metaphor of a map was used in representing adaptive learning paths. These learning path maps were constructed using different perspectives from cartography and geomatics, pedagogy, didactics, information visualization, and computer science. The visualization technique proposed can facilitate a practical method for representing the adaptive learning network, allowing for greater comprehension and discussion, according to the authors.

Brusilovsky, P., & Maybury, M. T. (2002). From adaptive hypermedia to the adaptive web. *Communications of the ACM, 45*(5), 30-33. http://dx.doi.org/10.1145/506218.506239
Cited by 496

The authors described the adaptive web as a promising research area. They defined an adaptive system as one that distinguishes between users including their knowledge goals and interests, and an adaptable system as one requiring the user to specify exactly how the system should be different. Research threads identified by the authors included navigational adaptive systems that manipulate the links a learner accesses with Web pages, (content) tailored to user preferences, and adaptive systems that provide customized content selection/learning paths via user modeling.

Chaoui, M., & Laskri, M. T. (2013). Proposition and organization of an adaptive learning domain based on fusion from the web. *Educational Technology & Society, 16*(1), 118-132. Retrieved from: http://www.ifets.info/journals/16_1/11.pdf
Not yet cited

The authors noted that there is a huge amount of information on the Web that can be used for self-learning. However, obtaining the most appropriate resources can be a challenge, as there is a need for reliability, learner satisfaction, and the need to acquire the most relevant content. To meet this challenge, the authors developed PrOALDoF-Web "Proposition and Organization of an Adaptive Learning Domain based on Fusion from Web." The authors described the value of their project as a system adaptation that allowed the tracking of learners, their habits, and decisions in order to present the appropriate content. The system was used to construct an adaptive learning domain customized to individual learner profiles. In their experimental study, the authors found that the adaptation of extracted Web resources was of sufficient reliability and quality to satisfy learners. The authors suggested that instructors can easily create and amend courses in the system to yield effective content based on the richness of resources available on the Web. The ability to re-use content resources was cited as another benefit. However, the authors indicated that use of domain resource

ontologies and semantic rules may present some difficulties unless more resources were applied to improve upon the efficiency of their approach.

Chen, C.-M. (2008). Intelligent Web-based learning system with personalized learning path guidance. *Computers & Education, 51*(2), 787–814. Elsevier. http://dx.doi.org/10.1016/j.compedu.2007.08.004
Cited by 108

Chen indicated that adaptive learning systems that utilize learner preferences, learning style or learning behavior while failing to consider learner ability can result in a mismatch between learning object/content difficulty and learner ability, leading to cognitive overload and failure of the personalized learning path for the student. Chen reported on the design and initial results of an experimental learning system designed to optimize individual learning. The system used a genetic algorithm that considered courseware difficulty and concept continuity to generate an optimal learning path based on a student's incorrect responses to a course pre-test. Chen provided detailed information and graphics describing the system architecture and components, the step-by-step operational procedures, and course modeling based on Computer Assisted Testing (CAT) and Item Response Theory (IRT). An underlying assumption was that the course content or courseware corresponding to a given test question also matched the difficulty level of the test question. Additionally, the system was dependent on SCORM meta-data maintained in the XML binding files of the content to convey course concept. Chen provided a detailed report of how the metadata was preprocessed and how the relationship of concepts between testing items and content was estimated using a vector space model. He also described the algorithm, which uses chromosomes and genes as a metaphor, to describe how the serial numbers of courseware relate to each other in order to arrive at an individualized course sequence that is mindful of the need for concept continuity in the prescribed learning path.

Chen, C.-M., Lee, H.-M. & Chen, Y.-H. (2005). Personalized e-learning system using Item Response Theory. *Computers & Education, 44*(3), 237–255. Elsevier.
http://dx.doi.org/10.1016/j.compedu.2004.01.006
Cited by 242

In this proof of concept study, Chen applied Item Response Theory (IRT) to the design prototype for an online learning system that recommended and rank-ordered course materials based on student ability. Whereas IRT in Computer Adaptive Testing (CAT) relies on demonstrated learner ability via responses to test questions to adjust the difficulty level of the next item presented, in this system, learner ability was stated by the students as a yes/no response to a question about their perceived comprehension of the material presented. Chen also documented the hardware/database/scripting configuration used and illustrated the system architecture. Course designers and subject experts assigned one of three difficulty levels to the course materials available in the system. Students were initially presented with non-personalized course materials and after exploring some of the content, they received two question prompts from the system, a Likert scale question regarding their perception of the difficulty of the material viewed and a yes/no question about their comprehension of the material. Difficulty level of the next ranked set of materials recommended was tuned to the initial student responses. Each time students viewed material, the yes/no question on comprehension followed. According to Chen, tuning for difficulty level using collaborative voting (many students answering the same comprehension question for the same content) controled for abnormal individual student responses over time and improved the accuracy of the tuning, and ultimately, the quality of

the recommendations presented to each student. In an experimental test of the system, 35 course content items with various difficulty levels were made available to 210 logged learners studying neural networks as part of a graduate degree program. The results showed a high correlation between difficulty of material recommended by the system and the learners' abilities. Survey results reflected high learner satisfaction with the system's ability to recommend and rank order materials, the moderate level of difficulty of the materials presented, and the students' ability to understand the materials.

de Palo, V., Sinatra, M., Tanucci, G., Monacis, L., Di Bitonto, P., Roselli, T. & Rossano, V. (2012). How cognitive styles affect the e-learning process. *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 359–363). http://dx.doi.org/10.1109/ICALT.2012.79
Cited by 2

Four student cognitive learning styles were analyzed along with additional factors affecting learning, such as attitudes, motivation, and resilience. The study also examined the efficacy of learning objects that were tailored to students' cognitive styles of learning. A (Sharable Content Object Reference Model) (SCORM) was applied to an LMS in order to promote learning object reusability and interoperability of learning content. The use of adaptive hypermedia learning systems together with intrinsic motivational tools was found to be an important component of a successful learning environment. The authors suggested that a broader sample of students from different courses would further aid in validating the results of their study.

Dias, S. M., Reis, S. & Zampunieris, D. (2012). Personalized, adaptive and intelligent support for online assignments based on proactive computing. *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 668–669). http://dx.doi.org/10.1109/ICALT.2012.223
Cited by 2

The authors noted that most existing learning management systems (LMS) only provide content based on student request rather than the personal, immediate support that a teacher would offer in a classroom, based on observation of the student's needs. The authors designed a prototype system, bolted on to an existing LMS, to improve upon the learning experience. The prototype provided personalized, adaptive, and intelligent support to both the online students and the instructors. The authors asserted that the generic tool they developed can be readily adapted to any LMS system. Future plans included further design and implementation of additional proactive scenarios to further improve LMS functionality.

Dolog, P., Henze, N., Nejdl, W. & Sintek, M. (2004). Personalization in distributed e-learning environments. *Proceedings of the 13th international World Wide Web conference on Alternate track papers & posters* (pp. 170–179). http://dx.doi.org/10.1145/1013367.1013395
Cited by 296

The authors described their prototype work on the ELENA Project, which used a service-based architecture and semantic Web technologies to integrate adaptive/personalization services based on learner profiles with distributed or decentralized and open access e-learning repositories. Their prototype design described a personalized search function that incorporated user profile information, such as existing knowledge of the topic, learning style preferences, etc., and a personalized link generation service that included annotations, related content links, and contextual information about each result, such as costs, device requirements, or whether the content was part of a larger course.

Underlying support consisted of mapping, query, query rewriting, ontology, recommender, and repository services. Additionally, a user interaction component connected learner queries with subject ontologies.

At the core of the prototype design was a personalized learning assistant integrating all of the other services. The authors also examined and provided related research citations for underlying semantic Web technologies and emerging standards used to provide services, define metadata schemas and domain ontologies, and provide learner and content descriptions, including RDF/S, DAML+OIL, OWL, Dublin Core, IEEE PAPI, IMS LIP, and TRIPLE. Finally, the authors contrasted their prototype design and use of encapsulated and reusable TRIPLE rules to *AHA!* and other adaptive hypermedia systems that used XML-encoded rules for adaptation functionality.

Essalmi, F., Ayed, L. J. B., Jemni, M., Graf, S. & others. (2010). A fully personalization strategy of E-learning scenarios. *Computers in Human Behavior, 26*(4), 581–591. Elsevier. http://dx.doi.org/10.1016/j.chb.2009.12.010
Cited by 33

In their review of the literature, the authors found that most adaptive learning systems used no more than three pre-defined personalization strategies. The authors identified 16 personalization parameters (combined here) and provided citations for the literature in which these parameters were studied. The parameters included: pedagogy (objectivist, competency-based, etc.), information seeking task, progress on task, elapsed response time, cognitive traits such as processing speed/reasoning ability, learners' knowledge levels, learning goals, media preferences, language preferences, navigation preferences, participation levels, motivation levels, and learning styles. Specific learning styles included Kolb's (1984) four-stage experiential learning model (Concrete Experience, Reflective Observation, Abstract Conceptualization and Active Experimentation); Honey-Mumford (1986) (Activist, Reflector, theorist, and Pragmatist), Felder-Silverman's (1988) styles describing how learners receive and process information (Sensing/Intuiting, Visual/Verbal, Active/Reflective, and Sequential/Global); and La Garanderie (1993) interactive styles (competitive, cooperative, avoidance, participative, dependent, independent). According to the authors, more than 58,000 personalization strategies are possible using various combinations of just 10 of the available personalization parameters. The authors proposed a service architecture where instructors (or designers) could select a subset set of personalization parameters appropriate to a given course, combine them, then map to specific content to create learning scenarios that could be dynamically delivered to learners in accordance with the information contained in the learner profiles, such as previous knowledge or learning style.

Graf, S., & Ives, C. (2010, July). A flexible mechanism for providing adaptivity based on learning styles in learning management systems. In *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference* on (pp. 30-34). IEEE. http://dx.doi.org/10.1109/ICALT.2010.16
Cited by 16

The authors posited that adaptive learning systems are an essential element to enhancing student learning experiences and online satisfaction levels. An adaptive mechanism was proposed that pointed towards 12 types of learning objects that could easily be inserted into the course without a requirement that they be included in all sections of the course, thus affording greater instructor flexibility. The Felder-Silverman Learning Style Model, considered to be the most widely used in

adaptive learning systems, was used by the authors. Adaptation features were incorporated into the LMS to facilitate course set-up by instructors for students with different learning styles.

Hsiao, I.-H., Sosnovsky, S. & Brusilovsky, P. (2010). Guiding students to the right questions: adaptive navigation support in an e-lLearning system for Java programming. *Journal of Computer Assisted Learning*, *26*(4), 270–283. Wiley Online Library. http://dx.doi.org/10.1111/j.1365-2729.2010.00365.x
Cited by 22

The authors explored adaptive navigation support that provided specific personalized guidance to students in an e-learning environment. Three semesters of a Java programming course were used to test the ability of the developed system in selecting appropriate interactive questions to assist students in learning the course materials. The authors found that the system was able to guide students to an appropriate question based on their skill level and understanding of the course material. Personalized guidance through adaptive problem generation and adaptive problem selection allowed students to focus on problems of optimal difficulty thus facilitating and enhancing the learning experience. The authors also found that students were two and a half times more likely to answer a quiz question correctly with adaptive navigation support than without it. According to the authors, the study confirmed that adaptive navigation support provided specific personalized guidance resulting in improved student comprehension and improved efficiency of the educational process.

Huang, Y.-M. & Liu, C.-H. (2009). Applying adaptive swarm intelligence technology with structuration in web-based collaborative learning. *Computers & Education*, *52*(4), 789–799. Elsevier. http://dx.doi.org/10.1016/j.compedu.2008.12.002
Cited by 31

The authors proposed a collaborative learning environment based on swarm intelligence systems (SIS). The authors posited that such a system could structure opportunities for effective learner collaboration and dynamically advance learning opportunities, thereby increasing the efficiency of the learning environment. The authors drew on structuration theory and adaptive structuration theory (AST), which suggest that groups are likely to find ways to adapt and collectively compensate for any obstacles that they may face. According to the authors, SIS can be utilized to manage "computationally intensive" tasks more effectively and improve learning effectiveness via self-organizing behavior and multi-agent mechanisms. The ASCL environment also outperformed a general Web based learning environment. The authors concluded that swarm intelligence technology can help learners overcome obstacles and assist them in adapting to a Web-based collaborative learning environment.

Karampiperis, P. & Sampson, D. (2005). Adaptive learning resources sequencing in educational hypermedia systems. *Educational Technology & Society*, *8*(4), 128–147. http://www.ifets.info/journals/8_4/13.pdf
Cited by 138

According to the authors, substantial effort was required on the part of designers for rules-based adaptive systems in order to produce consistent and accurate rule sets. In the absence of perfect rules, the learning paths (content sequences) generated were characterized by conceptual gaps, which is less than ideal. The authors proposed an alternative adaptation model to control the run-time

behavior of the system. In this model, pre-defined concept and content selection rules were replaced with a decision tree approach that mapped the description of the learning resources to learning style and preferences stored in the User Model component of the system. Based on simulations of their proposed system, the authors concluded that the learning paths produced were sufficient and that development of a perfect rule-based AEHS may not be necessary. The success of the system, according to the authors, was prefaced on structured (rather than raw) learning resources and the aggregation level that was specified in the media space. Additionally, the authors indicated that their future research would be aimed at better sequencing of raw media and incorporation of additional pedagogical designs focusing on separating learning scenarios from the adaption decision model.

Klavsnja-Milicevic, A., Vesin, B., Ivanovic, M. & Budimac, Z. (2011). E-Learning personalization based on hybrid recommendation strategy and learning style identification. *Computers & Education, 56*(3), 885–899. Elsevier. http://dx.doi.org/10.1016/j.compedu.2010.11.001
Cited by 61

The authors presented the results of a four-month study involving 440 undergraduate students, 340 of whom (control group = 100) used an intelligent tutoring system for introductory programming skills in Java. Individual student profiles were created and stored in the system's leaner module during the registration process. Students manually entered demographic and background information, including previous knowledge, interests, etc. Additionally, data on preferred modes of instruction were collected from the students via a 44-question Index of Learning Styles instrument, which categorized learning styles along the four dimensions: Information Processing (active/reflective); Information Perception (sensing/intuitive); Information Reception (visual/verbal); and Information Understanding (sequential/global) (Felder & Soloman, 1996). In this system, learners were able to manually edit their profile information to change their learning style preferences. The system clustered learners into 16 categories based on individual learning styles and used the AprioriAll algorithm (Tong & Pi-Lian, 2005) to mine the behavioral patterns of each learner, including specific pages visited, sequential page viewing patterns, quiz results, and grades. The authors designed an automated collaborative filtering approach that compared knowledge and navigational sequences among learners to provide recommendations at the beginning of the next learning session. The authors believed the combined approach of the data-mining algorithm and collaborative filtering performed by the system provided for accuracy and dynamic, current recommendations.

According to the authors, "learners only benefit from learning technology when it makes learning more effective, efficient or attractive" (p. 897). The authors found that leaners who used the system completed more course requirements successfully, and at a faster rate than the control group. A survey of a randomly selected group of students from the experimental group showed that 70% viewed the system as convenient and helpful. More than half were satisfied with the speed and accuracy of the system. Future research planned by the authors includes combining the aforementioned techniques with user generated content tags and annotations.

Prepared by Kate Ford, Center for Innovation in Learning
Last updated 12/12/2013
Cited by numbers (via Google Scholar) current as of 12/12/2013

Knauf, R., Sakurai, Y., Takada, K. & Tsuruta, S. (2010). Personalizing Learning Processes by Data Mining. *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on* (pp. 488–492). http://dx.doi.org/10.1109/ICALT.2010.141
Cited by 1

The authors employed a storyboarding technique to model student curricula and to follow student progress in their studies. The storyboard concept was explained as a hierarchy of graph nodes and edges. A data mining technique was also introduced that estimated the chances for student successful completion of the assignment at hand. Successful patterns of former students who completed the paths were analyzed and the storyboards were adjusted to improve the chances of student success. The process was further refined by the introduction of individual student preferences and skills.

Lazarinis, F., Green, S. & Pearson, E. (2010). Creating personalized assessments based on learner knowledge and objectives in a hypermedia Web testing application. *Computers & Education, 55*(4), 1732–1743. Elsevier. http://dx.doi.org/10.1016/j.compedu.2010.07.019
Cited by 19

The paper focused on Computerized Adaptive Testing (CAT) systems. A Web testing system was proposed, which adapts based on student performance, instructional goals, and test participants existing knowledge of the subject matter. The authors focused on the authoring process and provided examples where instructors authored different adaptive assessments for various scenarios. The instructors were able to apply different rules to the same test based on individual student data and learning profiles. According to the authors, instructors felt they were able to use their teaching experience in tailoring tests to the characteristics of their learners' profiles. The authors also found that instructors would benefit from the development of a help system when problems arise during utilization of the tool.

Lo, J.-J., Chan, Y.-C. & Yeh, S.-W. (2012). Designing an adaptive web-based learning system based on students' cognitive styles identified online. *Computers & Education, 58*(1), 209–222. Elsevier. http://dx.doi.org/10.1016/j.compedu.2011.08.018
Cited by 14

The authors called for more attention to cognitive learning style differences between students in how they perceive and process information while navigating Web. Rather than using questionnaires or forms, three classes of college freshmen were observed during their web browsing activities to determine their cognitive learning styles. Adaptive interfaces were then designed based on the results. The authors found that their proposed system could identify students' cognitive styles with a high degree of accuracy.

Nitchot, A., Gilbert, L. & Wills, G. B. (2010). Towards a competence based system for recommending Study Materials (CBSR). *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on* (pp. 629–631). http://dx.doi.org/10.1109/ICALT.2010.179
Cited by 3

The authors identified the deficiencies in existing adaptive learning systems, specifically user modeling, which was inconsistent in application and dependent on instructor intervention. The

authors explored a Competency Based System for Recommending Study Materials (CBSR) that removed the instructor-based intervention and automatically suggests web based study materials to the student. According to the authors, the CBSR system can develop a better profile of student competencies, which is consistent with competency models supporting lifelong learning and pedagogical approaches.

Sampson, D., Karagiannidis, C., Kinshuk, D. & others. (2010). Personalised learning: educational, technological and standarisation perspective. *Digital Education Review*, (4), 24–39. Retrieved from http://greav.ub.edu/der/index.php/der/article/viewArticle/44
Cited by 108

The authors examined and discussed personalized learning environments from the educational, technological and standardization perspectives, concluding that the shift to more personalized learning is consistent with just in time learning and learning on demand environments.

Simko, M., Barla, M. & Bieliková, M. (2010). ALEF: A framework for adaptive web-based learning 2.0. Key *Competencies in the Knowledge Society* (pp. 367–378). Springer. http://dx.doi.org/10.1007/978-3-642-15378-5_36
Cited by 44

The authors proposed a methodology for a next generation LMS system design based on present Web 2.0 concepts, enhanced by personalization and adaptation, while also retaining reusability and providing for ease of maintenance of learning content and metadata. Their framework, ALEF (Adaptive LEarning Framework) was designed to allow flexible course authoring affording efficient usage of metadata extraction based on lightweight semantics. The authors believed that the integration of the learning and supporting activities into a single framework represents a significant contribution. The authors tested the feasibility of the proposed framework via Moodle integration and creation of a programming course. By personalizing the learning experience via a combination of texts and interactive objects, the authors believed the learning experience, student engagement and and knowledge retention was improved.

Surjono, H. D. (2011). The design of adaptive e-learning system based on student's learning styles. *International Journal of Computer Science and Information Technologies*, 5, 2350–2353. Retrieved from: http://ijcsit.com/docs/Volume%202/vol2issue5/ijcsit20110205108.pdf
Cited by 5

Surjuno discussed an adaptive learning system design based on students' natural learning preferences -- visual, auditory or kinesthetic. Student preferences were further categorized based on whether the student prefers to learn in a sequential step-by-step manner or globally in theoretical application. Questionnaires were used in the system design to determine students' learning styles and to categorize the students. The system then presents course materials aligned with the students' learning styles.

Tugsgerel, B., Anane, R. & Theodoropoulos, G. (2010). An integrated approach to learning object sequencing. *Advanced Learning Technologies (ICALT), 2010 IEEE 10th International Conference on* (pp. 105–109). http://dx.doi.org/10.1109/ICALT.2010.37
Not yet cited

The authors proposed a framework involving the metadata of the learning object and learner profiles. The authors noted the sequencing of learning objects into a student's personalized learning paths provided a more personalized and efficient learning experience. The framework also allowed for learning objects from different providers can be used and tailored to individual students learning styles and sequenced to match student learning profiles.

Intelligent Tutoring Systems

Bowen, W. G. & Ithaka, S. (2012). *Interactive learning online at public universities: Evidence from randomized trials*. Ithaka S+ R. Retrieved from http://www.sr.ithaka.org/research-publications/interactive-learning-online-public-universities-evidence-randomized-trials
Cited by 20

This report described the results of randomized study involving 605 traditional age college students that was conducted by Ithaka to examine and compare learning outcomes achieved via a traditional classroom model for teaching introductory statistics and a hybrid model that combined learning via interactive intelligent tutor (developed by Carnegie Mellon University) with once-per-week classroom instruction and assistance. University of Maryland, Baltimore County and Towson University were among the six public four-year universities involved in the study. A slight, but not statistically significant, performance gain among the hybrid students was observed in course pass rates, final exam scores, and scores on a standardized statistical literacy test. The results were nearly identical with and without controlling for variables such as student demographics, full-time/part-time status, primary language and number of courses previously completed (year in college). The hybrid students spent about 25% less time on the course than the traditional students. In terms of satisfaction, students rated the hybrid format less favorably, indicating that the course was more difficult and that they felt they learned less. The authors provided a cost simulation, which may not be generalizable to all university or college scenarios, which suggested that the prototype course model may result in cost savings, primarily in the area of instructional inputs.

Chi, M., VanLehn, K., Litman, D. & Jordan, P. (2011). Empirically evaluating the application of reinforcement learning to the induction of effective and adaptive pedagogical strategies. *User Modeling and User-Adapted Interaction, 21*(1-2), 137–180. Springer. http://dx.doi.org/DOI 10.1007/s11257-010-9093-1
Cited by 14

According to the authors, the fixed pedagogical policy employed by most intelligent tutoring systems limits their adaptability. Citing previous research, the authors indicated that only model-free reinforcement learning induced policies in an Intelligent Tutoring System had been empirically evaluated using real students, and though they resulted in faster learning, no improvement in learning outcomes was achieved. Rather than use simulated students or pre-existing data for training, the authors trained human students on Cordillera, a Natural Language Intelligent Tutoring System for introductory physics. They used a model-based reinforcement learning algorithm to infer instructional rules (rather than hand-coding them in advance) from a small corpus that was collected by allowing the system to make random decisions when interacting with real students during the training phase. Cordillera was tested with a new set of students to determine whether the inferred rules improved learning outcomes rather than simply reducing task time, or improving student

satisfaction with the dialogue system. The authors found that the effectiveness and student learning gains improved significantly. Extensive details on the process were provided in this 45-page paper.

Jeremic, Z., Jovanovic, J. & Gasevic, D. (2012). Student modeling and assessment in intelligent tutoring of software patterns. *Expert Systems with Applications, 39*(1), 210–222. Elsevier. http://dx.doi.org/10.1016/j.eswa.2011.07.010
Cited by 14

The authors presented findings from their design and experimental testing of a domain-independent student model in an intelligent tutor, DEPTHS (Design Pattern Teaching Help System), which was designed for helping students learn software design patterns. Two common modeling approaches, namely stereotype and overlay were used. Student knowledge levels were assessed using both fuzzy logic and rules. Based on their findings, the authors suggested that DEPTHS improves student motivation and may lead to faster improvements in learning performance. The authors indicated that future improvements to the system were planned, including providing learners with context aware services. Additionally, the authors compared DEPTHs to another pattern learning intelligent tutoring system, Pattern Guru, which is based on open source code and used a problem-based approach. According to the authors, Pattern Guru represented more of an extension to, rather than replacement for the DEPTHs system, as it did not support adaptive learning via the use of a student model.

Johnson, B. G., Phillips, F. & Chase, L. G. (2009). An intelligent tutoring system for the accounting cycle: Enhancing textbook homework with artificial intelligence. *Journal of Accounting Education, 27*(1), 30–39. Elsevier. http://dx.doi.org/10.1016/j.jaccedu.2009.05.001
Cited by 21

The authors presented a case study examining the use of an artificial intelligence (AI) system (http://quantumsimulations.com/) to assist students in learning the accounting cycle (transaction analysis and ledger posting) more effectively. Two sections of an accounting course representing 55 students were involved. One section used the AI system, while the other used traditional textbook review content. The authors found that use of the AI tutor during problem-solving practice resulted in improvement of student comprehension and understanding of the accounting cycle. Specifically, after completing a 50 minute assignment, those students who used the AI tutor achieved a 25% performance gain on a subsequent test, compared to only an 8% improvement in score among the students who relied on their textbooks and notes. The authors discussed directions for additional research comparing the AI tutors results to homework management systems and live human instructors and matching AI feedback to students' cognitive learning styles.

Melis, E., Faulhaber, A., Doost, A. S. & Ullrich, C. (2010). Supporting flexible competency frameworks. *Advances in Web-Based Learning-ICWL 2010* (pp. 210–219). Springer. http://dx.doi.org/10.1007/978-3-642-17407-0_22
Cited by 2

The authors described how ACTIVEMATH integrated several competency based systems and allowed the re-use of learning objects. The student model interface allowed it to translate elements of various competency systems into pairs of concepts and cognitive processes. The authors asserted that the ability to search for learning objects among various competency systems based on a specific

hard-coded competency positively impacted the generated course materials. They also suggested that competency related data can be ontologically mapped and referenced to the internal systems currently in use.

Phobun, P. & Vicheanpanya, J. (2010). Adaptive intelligent tutoring systems for e-learning systems. *Procedia-Social and Behavioral Sciences, 2*(2), 4064–4069. Elsevier. http://dx.doi.org/10.1016/j.sbspro.2010.03.641
Cited by 22

This article discussed combining two types of learning management systems to serve as a model that will build on the strengths of each system to provide both conceptual based instruction combined with improved skill practice. The authors described Adaptive Hypermedia Systems (AHS) as providing a conceptual approach to learning whereas, Intelligent Tutoring System (ITS) adapted to the student's knowledge base and learning style to assist students in using established concepts as an aid in finding solutions. The authors suggested that combining the two systems into a single Adaptive Intelligent Tutoring System (AITS) builds on the strengths of each system and draws on more student data to provide conceptualized instruction and practice in putting the concepts into practice.

Gaming In Relation to Adaptive Learning

Hendrix, M., Protopsaltis, A., Rolland, C., Dunwell, I., de Freitas, S., Arnab, S., Petridis, P., et al. (2012). Defining a metadata schema for serious games as learning objects. *eLmL 2012, The Fourth International Conference on Mobile, Hybrid, and On-line Learning* (pp. 14–19). Retrieved from: http://www.thinkmind.org/index.php?view=article&articleid=elml_2012_1_30_50045
Cited by 3

Noting educators growing interest in using serious games for learning, the authors posited that metadata schemas are required to capture data and that systems must use this metadata beyond its original scope. They proposed a metadata schema using existing technologies and metadata standards to assist in the evaluation of games as potential learning objects. The authors believed the introduction of such a metadata schema for serious games will allow them to be categorized in online learning repositories. Future plans included developing a rating tool that will enable sharing of individual experiences with the use of these games as a learning resource.

Adaptive Mobile-Learning

Gomez, S., Zervas, P., Sampson, D. G. & Fabregat, R. (2012). Delivering adaptive and context-aware educational scenarios via mobile devices. *Advanced Learning Technologies (ICALT), 2012 IEEE 12th International Conference on* (pp. 197–201). http://dx.doi.org/10.1109/ICALT.2012.200
Cited by 5

This conference paper focused on the growth of mobile devices and how to integrate adaptive and personalized learning with mobile learning. The authors asserted that mobile devices are capable of being more personalized and customized to fit the user's preferences, but tools are needed to process this context based information. Such tools must be capable of adapting and changing to the

individual students learning styles. The authors presented a proposed mobile solution that incorporates adaptive learning technologies to provide context-aware learning based opportunities.

Karadimce, A. & Davcev, D. (2013). Adaptive multimedia learning delivered in mobile cloud computing environment. *CLOUD COMPUTING 2013, The Fourth International Conference on Cloud Computing, GRIDs, and Virtualization* (pp. 62–67). Retrieved from http://www.thinkmind.org/index.php?view=article&articleid=cloud_computing_2013_3_10_20016
Not yet cited

The authors prototyped a "Platform as a Service" or PaaS framework for adapting and delivering streaming multimedia content to students' mobile phones based on visual/verbal content preferences and current network conditions. The goal was to overcome device limitations, such as storage, processing power and bandwidth by offloading the multimedia processing from the device to the mobile cloud. In the simulated prototype using Oracle APEX, a single-question based on the Verbal-Visual Learning Style Rating (Mayer & Masser, 2003) was presented on the first use of the application, with the answer saved to the user profile database for the current and subsequent interactions. Based on a user's learning style and the detected device type and network context, the service delivered dynamic, high bandwidth content, such as video or more static media, such as text and images. The authors' experiment was successful in reducing performance load, but only the Android device OS, versus the Symbian and Apple iPhone OS, were able to present the content correctly, highlighting the on-going challenge in providing adaptive content to multiple mobile devices.

Wearable Technology/Sensors

Szafir, D. & Mutlu, B. (2012). Pay attention!: Designing adaptive agents that monitor and improve user engagement. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 11–20). Retrieved from http://pages.cs.wisc.edu/~bilge/pubs/2012/CHI12-Szafir.pdf
Cited by 13

The authors made use of both physical and virtual embodied agents that afforded interaction with students using behavioral, emotional, and physical clues. These agents improved upon the student learning experience by monitoring the student's cognitive behavior patterns and employing methods to increase student attention, motivation, mental alertness and involvement in the learning activity. Using brain computer interfaces (BCI) and educational psychology techniques, intelligent agents were designed to monitor student attention in real time through the use of EEG brain activity monitoring. When the EEG sensors recorded student inattention, a robotic agent reacted by using immediacy clues such as increased vocal level, physical such as gestures, arm movement and smiling to recapture the students attention. In an experimental test, the robot agent told a story individually to 15 students. The authors found that overall recall ability increased 43% when immediacy clues where employed. Also, female students reported a significantly higher rapport and motivation using the adaptive learning robot. The authors recommended further study on the use of human-like interaction models.

Prepared by Kate Ford, Center for Innovation in Learning
Last updated 12/12/2013
Cited by numbers (via Google Scholar) current as of 12/12/2013

Bibliography

Brusilovsky, P. (1999). Adaptive and intelligent technologies for web-based education. *KI*, *13*(4), 19-25.

Felder, R. M., & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, *78*(7), 674–681.

Felder, R. M., & Soloman, B. A. (1996). Index of learning styles questionnaire. Retrieved 17 December 2009, from. http://www.engr.ncsu.edu/learningstyles/ilsweb.html.

Honey, P., & Mumford, A. (1986). A manual of learning styles. In Peter Honey & Maidenhead (Eds.), *Learning styles*. Engineering Subject Centre.

Kolb, D. A. (1984). Experiential learning: Experience as the source of learning and development. NJ: Prentice-Hall. In David A. Kolb, Richard E. Boyatzis, Charalampos Mainemelis (Eds.), *Experiential learning theory: Previous research and new directions*. R. J. Sternberg, L. F. Zhang (Eds.), Perspectives on cognitive, learning, and thinking styles. NJ: Lawrence Erlbaum (2000).

La Garanderie, A. (1993). Les profils pédagogiques. Paris, Bayard, Tunis, Publications de l'ATURED. In A. Chabchoub (Ed.), *Enseigner à l'Université de la théorie à la pratique*, 2006.

Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of educational psychology*, *95(4), 833*, *95*(4), 833.