Adaptivity and Autonomy Development in a Learning Personalization Process

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ABSTRACT Within the iClass (Integrated Project 507922) and Enhanced Learning Experience and Knowledge Transfer (ELEKTRA; Specific Targeted Research or Innovation Project 027986) European projects, the author was requested to harness his pedagogical knowledge to the production of educational adaptive systems. The article identifies and documents the pitfalls of such interdisciplinary joint work. It suggests that the pedagogical added value of adaptive tools is more likely to be found in the support of human decision making regarding personalization strategies, autonomy development and metacognitive training than in the provision of highly technical automatic customization devices.

Adaptivity: new word, historical concept

The personalization of learning has become prominent in the educational field at various levels: social (Bonal & Rambla, 1999, p. 208), government policy (Department for Education and Skills, 2004; Leadbeater, 2004), school management (Lambert & Lowry, 2004; West-Burnham & Coates, 2005) and course/lesson design (Tomlinson, 1999; Martinez, 2002; Weller et ala, 2003; Polhemus et al, 2004). Definitions of personalization vary greatly (Jennings, 2006; Noss, 2006, p. viii), from the perfectly acceptable 'antithesis of impersonal' to the technically focused 'automatically structured paths to meet the needs of the learner' or proposals which tend to equate the essence of personalization to metacognition, which allows the learner to understand him/herself as a learner and to make learning a personal matter. This latter orientation is the one we would gladly embrace. Since the mid 1990s, the discourse on personalization of learning has been feeding the development of adaptive hypermedia systems (Primus, 2005), the most recent metamorphosis of artificial intelligence's vision on education, embodied successively by intelligent tutoring systems, programmed instruction and computer-aided learning. The core idea remains the production, by a learning system, of automatic educational adjustments to the learner's profile. Following Burgos et al (2007) and Oppermann (1994), I refer to the machine-led process as 'adaptivity'. When the learning experience is tuned to the characteristics of learners (age, knowledge level, needs, objectives, preferences, styles, modalities, etc.) due to the action of human agents, the learner and/or the teacher, the word 'adaptation' is used.

Problems, Reminders and Reservations

Usually coming from the technical side, proponents of adaptive systems require from pedagogues that they provide 'rules' (von Neumann, 2000) to inform the initial modelling and all aspects of the adaptive process (selection, creation, sequencing, aggregation and distribution of available material). In most cases, however, a systematic and automatic application of pedagogical principles turns out to be disappointing, and even dangerous (Banks, 2004). My experience in the ELEKTRA

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(Enhanced Learning Experience and Knowledge Transfer) project, a game-based learning project [1], and iClass, an e-learning platform initially featuring innovative machine-led personalization functionalities [2], fits with this idea. I hereafter document some reasons why the dialogue between pedagogy and technology can be difficult in projects that are highly ambitious regarding the implementation of adaptive processes.

Pedagogy Remains an Unstructured Field of Problems

Enjoined to provide 'rules' for iClass and ELEKTRA, I have often had to answer either 'We do not know' or 'It all depends'. It is not that pedagogues are especially hesitant, cowardly, slow or clumsy. Their answers derive from their awareness that education remains, and has long been, an unstructured field of problems (Dreyfus, 1972; Allert et al, 2002, p. 17; Aviram & Richardson, 2004; Friesen, 2004, p. 2; Matan & Aviram, 2005, p. 9; West-Burnham & Coates, 2005, p. 39). These problems are characterized by an unlimited number of facts, features and situations, the interplay between which is not clearly known. Since few results can be generalized due to the highly situated character of learning (Lave & Wenger, 1991; Verpoorten, 1996, p. 55), the pedagogue is reluctant to state any set-in-stone machine-readable rules such as the ones adaptive systems are eager for. There is no such thing as a 'learning algorithm' that is optimal for all situations. The factors are numerous and very context-specific. In pedagogy, few things are proven several times; many things are proven only once; and many more things are not proven and remain in the realm of 'best educated guesses' (Merrill, 2000, p. 4; Anderson, 2004, p. 55; Hargreaves, 2005, p. 12). Does this mean that we are condemned to say nothing valid about pedagogy or to become totally relativist? Not necessarily. It means that we need to keep the teacher/learner wisdom and responsibility in the loop for choosing, pondering, organizing and adapting the specific influences of learning situations. It means that adaptive systems are rarely self-sufficient and that the major challenge lies in their articulation with non-adaptive components of the learning process (Belisle & Linard, 1996, p. 31; Depover et al, 1998). Educationists can pinpoint where adaptivity can properly be applied (and provide rules) but the area is certainly much smaller than the initial idea technologists might have. Moreover, in most cases, the rules provided will address 'principles or facilitators of learning' rather than learning itself. This reminder about the limitations of pedagogical expertise might sound obvious. Nevertheless, any fruitful joint work between adaptive technologies and pedagogy must take into account that, in the view of most pedagogues, the idea that technology can second-guess the needs of learners is superficially attractive but riddled with problems (Jennings, 2006), all the more so when it is deemed to be applied without human control. A strictly technology-centred perspective, and the bypassing of educators it often entails, raises fears that 'the machine has been delegated a problem which is and remains primarily a teaching problem' (Maragliano, 2004, p. 1).

The Transparency of Rules as a Condition for Acceptance
of Adaptive Systems by Teachers and Pedagogues

There are doubts that the use of intelligent tutoring systems and adaptive systems serving personalization purposes will soon spread in schools (see also Murray, 1999, p. 127; Ainsworth & Fleming, 2006, p. 132). Among the reasons given for this pessimistic forecast, Baker mentions an underrated one:

> Now, if a teacher, for example, is to accept devolution of part of responsibility for teaching to a machine, that individualises its instruction, then not only will the teacher have to manage the individualisation within a group (such as a class), but the teacher will also have to understand how that individualisation occurs in order to accept the devolution of responsibility. Software producers' manuals and demonstrations are unlikely to be sufficient in this respect; no doubt the system will have to be 'transparent', in some sense of the term, for teachers. This is one of the classic problems that faced expert systems. (Baker, 2000, p. 134)

The issue of transparency as a condition for pedagogical acceptance is also stressed by authors working in the realms of non-adaptive instructional design, personalized course delivery or teacher

professional development (Wiley, 1999; Rezeau, 2001, p. 295; Martinez, 2002; Friesen, 2004; Goodyear, 2004; Ip, 2005; Poumay, 2005). They advocate for the up-front adoption of some of the existing instructional events models (Wiley, 1999, p. 10; Martinez, 2002, p. 12; Leclercq & Poumay, 2005; Baumgartner & Heyer, 2007, p. 17) so that the instructional design and its rationale can be made 'explicit' or 'transparent' to the user, helping to defuse the 'neutrality' usually professed by providers of e-learning systems and standards. Without this transparency – namely, the precise knowledge of what exactly occurs between the ins and outs of the adaptive process – it is impossible to establish a proper pedagogical reflection on the conditions of use and potential benefits of the adaptive system. Within iClass, for instance, in an effort for pedagogical clarity and control, we (Verpoorten et al, 2005, p. 11) proposed to consider the personal learning path (PLP) execution as a function (f) of five personalization parameters with associated subcategories: PLP = f (intention [3: prepare for exam/revise/explore]; location [2: home/class]; duration [3: short/about an hour/leisurely]; profile [4: Kolb Learning Style Inventory]; skills [3: Bloom's taxonomy revised by Anderson & Krathwohl, 2001]). Combining all these categories independently results in 216 combinations. But, in reality, several combinations were either dropped or summed up by the system in order to keep the complexity manageable. The pedagogical reasons for the dropping, grouping or attribution of specific paths to specific profiles had, in my view, to be made transparent for users in order to help them to assess the value of the tool fairly. On several occasions, this quest for clarity and concreteness was put aside by highly technical discussions that remained impenetrable (Weller et al, 2003b, p. 1), if not incomprehensible, for the educationist, who sticks to a basic concern: what it means for an educator to work with those systems, tools and facilities, and how this affects the type of educational support they produce.

Pedagogical Return on Expensive Adaptive Developments

Ainsworth & Fleming note:

> Designers of intelligent tutoring systems [ITSs] hope that one day their systems will perform as well as expert human tutors, which, in itself, is a very high goal. Bloom (1984) found that one-to-one tutoring by expert tutors, when compared to traditional whole class teaching, improves students' learning by 2 sigma effect size. This was the only pedagogical technique which had such a marked effect. Currently, state-of-the-art in ITSs is around a 1 sigma effect with evaluations of ITSs revealing effect sizes of between .4 and 1.2 compared to classroom teaching (e.g., Graesser, Person, Harter & The Tutoring Research Group, 2001; Koedinger, Anderson, Hadley, & Mark, 1997). However, the time and expertise needed to produce such clever systems has meant that such ITSs have not yet achieved widespread application in schools, colleges or workplaces – creating an ITS is estimated to take between 300 and 1000 hours to produce an hour of instructional material (e.g., Murray, 1999). (Ainsworth & Fleming, 2006, p. 132)

When reflecting on the 'return on investment', the educational benefit resulting from the personalization of learning obtained through adaptive systems can also be questioned. Studying the parameters selected by two adaptive systems, Monthienvichienchai (2005, p. 3) concludes that in many personalized learning projects, critics and advocates for particular adaptation parameters have emerged with an equal number of arguments for and against personalizing each parameter, with some even questioning the effectiveness of personalizing learning in the first place (Marzano, 1998), while others have recommended personalization with caution (for example, Ferguson et al, 2004). Commenting on Hattie's meta-analysis, the Coffield report on learning styles also casts doubts:

> The benefits of individualised teaching are often greatly exaggerated, although many teachers will admit that it is extremely difficult to ensure that learners are benefiting from specially tailored approaches when there is a large class to manage. In a synthesis of 630 studies, Hattie (1992) found an average effect size of only 0.14 for individualised teaching in schools. This trivial result strongly suggests that in general, it is not a good use of teacher time to try to set up, monitor and support individual learning programmes where there are large groups to deal with. It should be noted that the potential of ICT [information and

communication technologies] to support individualised instruction has not been fully evaluated. (Coffield et al, 2004, p. 146)

Hence, if the impact factor of personalized learning is questioned in the context of regular teaching, there should be an even greater amount of caution exercised when it comes to 'automatic customization', which adds its own assumptions and modelling filters (Dotan, 2006, p. 23). Matan & Aviram (2005, p. 8) note in addition that research in adaptive systems has still not yielded a scientifically corroborated set of methodologies to support personal learning and is flawed at an upper level by the lack of validated personalization theories. Better educational benefits measurements for adaptive systems are not necessarily just around the corner. As pointed out by Verpoorten & Logan (2006), there are relatively few examples of adaptive educational systems in practical use. Furthermore, those personalized learning platforms based on adaptive philosophy are seldom tested, remaining small-scale and mainly experimental set-ups. It goes without saying that this relative poverty should at the very least lead to empirical investigations (Weibelzahl, 2005) to demonstrate whether most effective learning is achieved or facilitated by such systems (Ronen, 2006, p. 19).

The Behaviourist Tropism of Adaptive Systems

'Every piece of education software, authoring tool or learning management services (LMS) implements a certain kind of learning theory. Every function of the software has underlying (tacit) pedagogical assumptions' (Baumgartner & Payr, 1999, p. 6). Adaptive systems are no exception. Both in iClass and ELEKTRA, the adaptive systems are based on domain knowledge representations, obtained by knowledge space theory (KST; Doignon & Falmagne, 1999), which strives to support the learner by scaffolding a domain of information towards his/her level of knowledge and subsequent learning needs. This cognitive toolbox, namely skills-based cognitive engineering, presents a solid and theoretical basis on which pedagogues must generate adaptive processes that are centred on the mastery of competences. It involves a hierarchy of concepts (Razek et al, 2003) and, thus, the system will present ordered activities to the learner, making sure that he/she will always be clearly positioned in the knowledge space that has been defined in the user model. This complex, mathematical and probabilistic way of positioning the learner in a knowledge space and, then, presenting adequate learning activities can be characterized as follows:

- KST is based on a teaching paradigm;
- KST has difficulty with ill-structured concept domains wherein knowledge and skills are fuzzier;
- KST is concerned with the adaptive capacities of the system while (constructivist) pedagogues will be more concerned with the development of pupils' capacities (Gipps, 1994, p. 25; Smith et al, 1997, p. 90);
- When establishing rules and algorithms that supply the 'rules' component of the system, KST refers to behaviourist theories where learning is seen as a mechanic, adding associations to existing ones;
- KST requests yes/no answers regarding skills mastery where there are several proficiency levels;
- Once a test has been successfully passed, there is no need to return to the activities that supported the acquisition of the skills. This is pedagogically disputable. Improvement is still possible when a test has successfully been passed (there may be a need for relearning, or the risk of forgetting or of structural regression).

At first sight, KST is wonderful because it tells what to teach and in what order. This is partly true but a problem of this elegant version of programmed instruction is that it ignores totally the variety of methods of learning. It can talk about the 'what' and, potentially, the 'in what order', but it says nothing about the 'how' or, more exactly, the 'how' is restricted to a standard problem resolution. According to the 8 Learning Events Model (Leclercq & Poumay, 2005), it means that only one major method of learning out of eight is trained. It is still difficult to see where it can be applied in the case of more constructivist approaches in less structured domains than mathematics. KST and similar adaptive processes are relevant as long as the conception of learning they support is made explicit and put into perspective with other views and approaches towards the same phenomenon.

After two projects based on this framework, the conditions for an adaptive system to support a non-behaviouristic-like learning process remains an open question for me.

Adaptivity and Self-Regulated Personalized Learning

However, should the previously described difficulties be overcome, is an automatic customization of learning a desirable endeavour per se? How does this challenge articulate with the apparently contradictory appeal of self-regulated (or self-personalized) learning which considers the learner not as an input of an intelligent rules-based system but as an active agent and possibly the main rule maker? Since the seminal article of Winne (1995), self-regulated learning (SRL) has gained momentum and become a pivotal construct in contemporary accounts of effective learning (Randi & Corno, 2000; Peters, 2004; Hargreaves, 2005, p. 18). In this context, SRL has been established as another facet of personalized learning that facilitates increased levels of learner empowerment. This emphasis on autonomy, self-regulation, metacognition or the ability of 'learning to learn' questions adaptive design: if adaptivity is about the design of made-to-measure learning, who is the bespoke tailor? In a narrow meaning, adaptivity will answer: 'the system'. But in so doing, does the adaptive system not disenfranchise the learner (Papert, 1992) of a crucial aspect of learning: autonomy or becoming a self-regulated learner? According to Boekaerts (1999, p. 449), three regulatory systems are involved in SRL: (1) the regulation of the self (choice of goals and resources); (2) the regulation of the learning process (use of metacognitive knowledge and skills to direct one's learning); and (3) the regulation of information processing modes (choice of information processing strategies). In their study of adaptive platforms according to a criteria matrix focused on what they offer or not in terms of personalized learning, Verpoorten & Logan (2006) point to the difficulty for adaptive platforms to support actions in Boeckaerts' second regulatory system. Even for the tools/platforms allowing some level of choice – a key component of SRL – either the metacognitive awareness is not mentioned or is mentioned in an evasive way, the main emphasis remaining obviously on delivery of customized paths versus paths 'on demand'. The automatically adaptive philosophy, eager to deliver 'optimized paths' to individuals, is, per se, bound to erase choice options whilst it represents a hallmark of SRL (Boekaerts, 1999, p. 447; Winne & Perry, 2000, p. 538; Paris & Paris, 2001; Paris & Winograd, 2001; Leadbeater, 2004, p. 10; West-Burnham & Coates, 2005, p. 41). Realizing the potentially destructive effect of an antagonism between the seminal assumption of their field ('the machine manages adaptivity') and the fundamental assumption of the SRL movement ('the learner must be in control as much as possible'), supporters of adaptivity are willing to take this piece of criticism into account. Some adaptive platforms (L3, AHA!, ActiveMath and some IMS LD [Instructional Management System Learning Design] experiments) are already offering some decision points to the student. From a theoretical standpoint, Magoulas et al (2003, p. 514), for example, include learner initiative in their definition of an adaptive system.

Conclusion and Move Forward

From the perspective of learners' control, it follows that a learning environment has to empower learners so that they are in control of and responsible for their learning, or should empower teachers as designers of personalized learning environments.[3] The above considerations do not deny the value of research in automatic customization procedures but urge for not giving adaptivity more than its due. In an aeroplane, the navigation instruments and control indicators available to the crew have been designed to support human decision making. Even when the automatic pilot is entrusted for parts of the journey, the possibility to check, during the flight, the correct execution of the journey plan remains intact and pilots can, at any moment, return to manual mode. Materializing that kind of real-time monitoring within learning processes would be of great benefit to education. It would revolve around the following questions: To what extent is this automatic customization of learning a plausible, desirable, safe and pedagogically productive objective? Where, when, how and for what learning benefits can automatic customization exist independently of human mediation? As pedagogues, we looked in both projects for a balance between what would be a 'Summerhill personalization' (the student decides everything) and a

'Robocop personalization' (the student decides nothing). Bowring-Carr & West-Burnham (1997), Patel & Kinshuk (1997) and West-Burnham & Coates (2005, p. 104) suggest intermediary positions in this spectrum, pointing at mutual support and articulation between adaptivity and adaptation. Actually, the median part of the spectrum defines a zone wherein adaptivity can support autonomy development. In this respect, Davis et al (2000, p. 96) suggest the concept of 'liberating constraints', namely providing learning paths combining some prestructured (by the teacher or the system) elements with a 'space of possibilities opened up only in the actual moment of learning'. Therefore, the role of the teacher or the system becomes to create activities that simultaneously limit and enable open choices (of strategies, activities, resources) and metacognitive reflection upon choices. The important question becomes: How can adaptive systems organize the conditions of the learner's autonomy and metacognitive development? This self-regulated personalization should be triggered, supported, visualized and assessed with the help of adaptive tools in productive ways. The focus moves from 'thinking like the learner' to 'thinking with the learner'. The move of adaptive systems towards more initiative and control left to learners opens pedagogically fruitful and coherent avenues.

Acknowledgements

Notes

[1] See http://www.elektra-project.org

[2] See http://www.iclass.info/

[3] On the urgent need for more implication of end-users in the design of learning systems, see Dillenbourg & Martin-Michiellot (1995), Hargreaves (2005, p. 14), Ainsworth & Fleming (2006), Brusilovsky et al (2006) and Organisation for Economic Co-operation and Development (2006, p. 2).

References

Ainsworth, S.E. & Fleming, P. (2006) Evaluating Authoring Tools for Teachers as Instructional Designers, *Computers in Human Behavior*, 22(1), 131-148. http://dx.doi.org/10.1016/j.chb.2005.01.010

Allert, H., Dhraief, H. & Nedjl, W. (2002) Meta-level Category 'Role' in Metadata Standards for Learning: instructional roles and instructional qualities of learning objects. Paper presented at COSIGN 2002, 2nd International Conference on Computational Semiotics for Games and New Media, Augsburg, 2-4 September.

Anderson, L.W. & Krathwohl, D.R. (2001) *A Taxonomy for Learning, Teaching, and Assessing: a revision of Bloom's taxonomy of educational objectives*. New York: Addison Wesley Longman.

Anderson, T. (2004) Toward a Theory of Online Learning, in T. Anderson & F. Falloumi (Eds) *Theory and Practice of Online Learning*, 33-60. Athabasca, Alberta: Athabasca University.

Aviram, A. & Richardson, J. (2004) Introduction: the widening void, in A. Aviram & J. Richardson (Eds) *Upon What Does the Turtle Stand? Rethinking Education for the Digital Age*. London: Kluwer Academic.

Baker, M. (2000) The Roles of Models in Artificial Intelligence and Education Research: a prospective view, *International Journal of Artificial Intelligence in Education*, 11(2), 122-143.

Banks, B. (2004) Personalised Learning: making the vision a reality with ICT. http://www.trainingpressreleases.com/newsstory.asp?NewsID=1296

Baumgartner, P. & Heyer, S. (2007) The Trinity: towards a model of learning objects. http://www.peter.baumgartner.name/article-de/trinity_model_of_lo.pdf/view

Baumgartner, P. & Payr, S. (1999) *Lernen mit Software: 2*. Innsbruck: Studien-Verlag.

Belisle, C. & Linard, M. (1996) Quelles nouvelles competences des acteurs de la formation dans le contexte des TIC ? *Education permanente*, 127(2), 19-47.

Boekaerts, M. (1999) Self-Regulated Learning: where we are today, *International Journal of Educational Research*, 31(6), 445-457. http://dx.doi.org/10.1016/S0883-0355(99)00014-2

Bonal, X. & Rambla, X. (1999) The Recontextualisation Process of Educational Diversity: new forms to legitimise pedagogic practice, *International Studies in Sociology of Education*, 9(2), 195-214. http://dx.doi.org/10.1080/09620219900200042

Bowring-Carr, C. & West-Burnham, J. (1997) *Effective Learning in Schools*. London: Pearson Education.

Brusilovsky, P., Knapp, J. & Gamper, J. (2006) Supporting Teachers as Content Authors in Intelligent Educational Systems, *International Journal of Knowledge and Learning*, 2(3-4), 191-215.

Burgos, D., Tattersall, C. & Koper, R. (2007) How to Represent Adaptation in eLearning with IMS Learning Design, *Interactive Learning Environments*, 15(2), 161-170. http://dx.doi.org/10.1080/10494820701343736

Coffield, F., Moseley, D., Hall, H. & Ecclestone, K. (2004) *Learning Styles and Pedagogy in Post-16 Learning: a critical and comprehensive review of learning style research, highlighting 13 core learning styles*. London: Learning and Skills Research Centre.

Davis, B., Sumara, D. & Luce-Kapler, R. (2000) *Engaging Minds: learning and teaching in a complex world*. Mahwah: Lawrence Erlbaum Associates.

Department for Education and Skills (DfES) (2004) *A National Conversation about Personalised Learning*. Nottingham: DfES Publications. http://www.standards.dfes.gov.uk/personalisedlearning/downloads/personalisedlearning.pdf

Depover, C., Giardina, M. & Marton, P. (1998) *Les environnements d'apprentissage multimédia: analyse et conception*. Paris: L'Harmattan.

Dillenbourg, P. & Martin-Michiellot, S. (1995) Intelligence artificielle et formation, *Interface*, 1, 6-10.

Doignon, J.-P. & Falmagne, J.-C. (1999) *Knowledge Spaces*. Berlin: Springer.

Dotan, I. (2006) *Self-Regulated Learning (SRL): how and to what extent does it improve learning?* iClass Report to Partners, iClass European project.

Dreyfus, H.L. (1972) *What Computers Cannot Do: the limits of artificial intelligence*. Cambridge, MA: MIT Press.

Ferguson, N., Schmoller, S. & Smith, N. (2004) Personalisation in Presentation Services. A Report commissioned by the UK Joint Information Systems Committee (JISC). http://www.therightplace.net/jp/

Friesen, N. (2004) Learning Objects and Standards: pedagogical neutrality and engagement. Paper presented at the IEEE International Conference on Advanced Learning Technologies, Joensuu, Finland, 30 August – 1 September.

Gipps, C.V. (1994) *Beyond Testing: towards a theory of educational assessment*. London: Falmer Press.

Goodyear, P. (2004) Towards a Pattern Language for Networked Learning. Paper presented at Networked Learning Conference 2004, Lancaster University, 5-7 April.

Hargreaves, D. (2005) *About Learning: report of the Learning Working Group*. London: Demos. http://www.demos.co.uk/publications/aboutlearning

Ip, A. (2005) BECTA's Packaging and Publishing LOs: best practice guidelines, *Random Walk in Learning*, 16 March. http://elearningrandomwalk.blogspot.com/2005/03/bectas-packaging-and-publishing-los.html

Jennings, D. (2006) FE White Paper: the personalisation virus is spreading. http://fm.schmoller.net/2006/04/fe_white_paper_.html

Lambert, M.B. & Lowry, L.K. (2004) *Knowing and Being Known: personalization as a foundation for student learning*. Seattle: Small Schools Project.

Lave, J. & Wenger, E. (1991) *Situated Learning: legitimate peripheral participation*. Cambridge: Cambridge University Press.

Leadbeater, C. (2004) *Learning about Personalisation*. London: Demos. http://www.demos.co.uk/publications/learningaboutpersonalisation

Leclercq, D. & Poumay, M. (2005) The 8 Learning Events Model and Its Principles. http://www.labset.net/media/prod/8LEM.pdf

Magoulas, G.D., Papanikolaou, K. & Grigoriadou, M. (2003) Adaptive Web-Based Learning: accommodating individual differences through system's adaptation, *British Journal of Educational Technology*, 34(4), 511-527. http://dx.doi.org/10.1111/1467-8535.00347

Maragliano, R. (2004) The Machine Has Been Delegated a Problem Which Is and Remains Primarily a Teaching Problem. Interview, 23 August. http://www.elearningeuropa.info/directory/index.php?page=doc&doc_id=5148&doclng=6

Martinez, M. (2002) Designing Learning Objects to Personalize Learning, in D.A. Wiley (Ed.) *The Instructional Use of Learning Objects*. http://www.reusability.org/read/chapters/martinez.doc

Marzano, R.J. (1998) *A Theory-Based Meta-analysis of Research on Instruction*. Aurora, CO: Mid-Continent Regional Educational Laboratory.

Matan, N. & Aviram, R. (2005) *iClass Project Formative Evaluation Report*. Internal Report to the Consortium, iClass European project.

Merrill, M.D. (2000) Instructional Strategies and Learning Styles: which takes precedence? In R. Reiser & J. Dempsey (Eds) *Trends and Issues in Instructional Technology*. Upper Saddle River, NJ: Prentice Hall.

Monthienvichienchai, P. (2005) *iClass M18 Interim Report*. London: Institute of Education.

Murray, T. (1999) Authoring Intelligent Tutoring Systems: analysis of the state of the art, *International Journal of Artificial Intelligence in Education*, 10(1), 98-129.

Neumann, J. von (2000) *The Computer and the Brain*. New Haven: Yale University Press.

Noss, R. (2006) Foreword, in G.D. Magoulas & S. Chen (Eds) *Advances in Web-Based Education: personalized learning environments*. Hershey, PA: Information Science Publishing.

Oppermann, R. (1994) *Adaptive User Support: ergonomic design of manually and automatically adaptable software*. Hillsdale: Lawrence Erlbaum Associates.

Organisation for Economic Co-operation and Development (2006) *Schooling for Tomorrow: futures thinking*. Paris: OECD.

Papert, S.A. (1992) *Mindstorms: children, computers and powerful ideas*. Cambridge, MA: Perseus Books.

Paris, S.G. & Paris, A.H. (2001) Classroom Applications of Research on Self-Regulated Learning, *Educational Psychologist*, 36(2), 89-101. http://dx.doi.org/10.1207/S15326985EP3602_4

Paris, S.G. & Winograd, P. (2001) The Role of Self-Regulated Learning in Contextual Teaching: principles and practices for teacher preparation. US Department of Education Project Preparing Teachers to Use Contextual Teaching and Learning Strategies to Improve Student Success in and beyond School (CIERA Archive#01-03). http://www.ciera.org/library/archive/2001-04/0104parwin.htm

Patel, A. & Kinshuk (1997) Intelligent Tutoring Tools in a Computer Integrated Learning Environment for Introductory Numeric Disciplines, *Innovations in Education and Training International Journal*, 34(3), 200-207. http://dx.doi.org/10.1080/1355800970340306

Peters, O. (2004) *Distance Education in Transition: new trends and challenges*, 4th edn. Studien und Berichte der Arbeitsstelle Fernstudienforschung der Carl von Ossietzky, vol. 5. Oldenburg: University of Oldenburg.

Polhemus, L., Danchak, M. & Swan, K. (2004) Personalized Course Development Techniques for Improving Online Student Performance. Paper presented at Conference of Instructional Technologies, Stony Brook University, New York, 1-4 June.

Poumay, M. (2005) Quality Evaluation: a challenge for online courses and catalogues, in E. Gard (Ed.) *Emdel: a model for valorization of eLearning in a knowledge society*. Oslo: European Model for Distance Education and Learning.

Primus, N.J.C. (2005) *A Generic Framework for Evaluating Adaptive Educational Hypermedia Authoring Systems: evaluating MOT, AHA! and WHURLE to recommend on the development of AEH authoring systems*. Twente: University of Twente.

Randi, J. & Corno, L. (2000) Teacher Innovations in Self-Regulated Learning, in M. Boekaerts, P.R. Pintrich & M. Zeidner (Eds) *Handbook of Self-Regulation*, 651-685. San Diego: Academic Press.

Razek, M.A., Frasson, C. & Kaltenbach, M. (2003) Web Course Self-Adaptation. Paper presented at the IEEE/WIC International Conference on Intelligent Agent Technology (IAT 2003), Halifax, Canada, 13-17 October.

Rezeau, J. (2001) *Médiatisation et médiation pédagogique dans un environnement multimédia*. Bordeaux: Université Victor Segalen Bordeaux 2.

Ronen, Y. (2006) *Customized Personal Learning (CPL): its effectiveness in improving learning results*. iClass Report to Partners. Tel Aviv: Ben-Gurion University.

Smith, E.M., Ford, J.K. & Kozlowski, S.W.J. (1997) Building Adaptive Expertise: implications for training design strategies, in M.A. Quiñones & A. Ehrenstein (Eds) *Training for a Rapidly Changing Workforce*, 89-118. Washington, DC: American Psychological Association.

Tomlinson, C.A. (1999) Mapping a Route toward Differentiated Instruction, *Educational Leadership*, 57(1), 12-16.

Verpoorten, D. (1996) *Pragmatics and Learning: a study of cognitive reasoning in dialogical situations*. Louvain-la-Neuve: Catholic University of Louvain.

Verpoorten, D. & Logan, K. (2006) *Benchmark of Prevailing Personalised Learning Platforms*. iClass Report to Partners. Liège: LabSET, University of Liège.

Verpoorten, D., Poumay, M. & Leclercq, D. (2005) *iClass Project (EC Integrated Project no. 507922) Intermediate Research Report M24*. Liège: LabSET, University of Liège.

Weibelzahl, S. (2005) Problems and Pitfalls in the Evaluation of Adaptive Systems, in S. Chen & G. Magoulas (Eds) *Adaptable and Adaptive Hypermedia Systems*, 285-299. Hershey, PA: IRM Press.

Weller, M., Pegler, C. & Mason, R. (2003a) Putting the Pieces Together: what working with learning objects means for the educator. Paper presented at the E-Learn International Conference, Phoenix, AZ, 7-11 November.

Weller, M., Pegler, C. & Mason, R. (2003b) Working with Learning Objects: some pedagogical suggestions. Paper presented at the ALT-C (Association for Learning Technology) Conference, Sheffield, 8-10 September.

West-Burnham, J. & Coates, M. (2005) *Personalizing Learning: transforming education for every child*. Stafford: Network Educational Press.

Wiley, D. (1999) Learning Objects and the New CAI: so what do I do with a learning object? http://opencontent.org/docs/instruct-arch.pdf

Winne, P.H. (1995) Inherent Details in Self-Regulated Learning, *Educational Psychologist*, 30(4), 173-187. http://dx.doi.org/10.1207/s15326985ep3004_2

Winne, P.H. & Perry, N.E. (2000) Measuring Self-Regulated Learning, in M. Boekaerts, P.R. Pintrich & M. Zeidner (Eds) *Handbook of Self-Regulation*. San Diego: Academic Press.

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