

# Rule-Based Mixed-Initiative Scaffolding

**Samir Menon**

Indian Institute of Information  
Technology.  
Allahabad, UP, India  
Email: sam@iiita.ac.in

**Jurika Shakya**

Simon Fraser University.  
Surrey, BC, Canada  
Email: shakya@sfu.ca

**Vive Kumar**

Simon Fraser University.  
Surrey, BC, Canada  
Email: vive@sfu.ca

## ABSTRACT

The mechanism of Self-Regulated Learning (SRL) is a complex interactive process involving cognitive self-regulation. Self-regulation is enacted by learners when they form specific learning strategies that they actively or sub-consciously adopt in order to enhance their learning experience. Our research concerns the development of a framework that allows for Mixed Initiative Interactions (MII) to help the learners optimize their learning strategies and help them self regulate better. We represent the underlying SRL tactics and strategies in an ontology. We utilize production rules to translate and disseminate SRL tactics and strategies represented in the ontology. This paper focuses on the design and development of the production rules. We describe how the production rules are employed in the context of a mixed-initiative system named MI-EDNA.

## Categories and Subject Descriptors

I.2.4 Knowledge Representation Formalisms and Methods  
– *representation languages, semantic networks.*  
I.2.6 Learning – *Knowledge Acquisition*

## Keywords

Mixed Initiative Interaction, Self Regulated Learning, Ontology, Semantic Web, Knowledge Representation, Production rules, Learning Tactics and Strategies, e-learning, Scaffolding, Intelligent Tutoring Systems, Fading.

## INTRODUCTION

Self-Regulated Learning (SRL) has been studied extensively as a possible means to help organize the tactics and strategies adopted by learners [18]. In e-learning environments, learners are exposed to multiple sources of online information in a non-linear manner. Learners are expected to adapt their learning strategies while studying these sources. Regulating one's tactics and strategies in an online learning environment requires planned learning processes

that use prior established knowledge along with the newly gained contextual information based on the principles of SRL to improve cognition [9]. Learners need to analyze the learning situation, set meaningful learning goals, and determine which strategies to use, assess whether the strategies are effective in meeting the learning goals, evaluate their emerging understanding of the topic, and determine whether the learning strategy is effective for a given learning goal [3]. A crucial skill of the learners that leads to their successful learning is the ability to self-regulate their cognitive processes and to remain self-motivated with regards to the task of collating the plethora of available information sources into a comprehensible amalgamation that may be used to satisfy their learning needs. In consideration of this, our research emphasizes the need for a system that scaffolds the learner to represent, recognize and regulate their cognitive processes.

Scaffolding involves modeling the learning task and gradually delegating responsibility to the students. It involves providing educational resources, problems or tasks for solving, templates for learner use and exhaustive cognitive guidance. Scaffolding provides the necessary support for the learners to successfully engage in a learning process. There are various degrees and types of scaffolding as explored in the fields of Intelligent Tutoring Systems and Educational Psychology [13]. In our approach, we consider scaffolding as a mechanism that allows learners to reflect on their tactics and strategies and to ground their reflection with respect to specific SRL models.

We have implemented the ontological representation of tactics and strategies employed by learners as part of their learning activities in a system named MI-EDNA. In MI-EDNA, we represent learner interactions in an ontology along with specific models of SRL. Specifically, we have an explicit representation of Zimmerman's [16] 3-phase SRL model in our ontology. We have also designed and developed production rules that match patterns of learner's cognitive processes with the tactics and strategies represented in the ontology. As a result of this pattern matching, we can trace the self-regulatory capabilities of the learners with respect to the underlying Zimmerman's SRL model and generate scaffolds that would help learners Self-Regulate with far greater ease. Detailed advice, direction of the learner's attention, and alerts to channel the sequence of activities are essential to for a learner to perform within the scaffolded environment. We hope to implement a scaf-

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

K-CAP'05, October 2-5, 2005, Banff, Canada.

Copyright 2005 ACM 1-58113-000-0/00/0000...\$5.00

folding mechanism that would help reduce cognitive load and lead to enhanced learning efficiency..

The rest of the paper presents an overview of Mixed-Initiative Interaction systems, a summary of scaffolding mechanisms across the domains of reading, composition, and problem-solving, a categorization of scaffolds that we employ in MI-EDNA, and finally discuss how we employ a rule-based inference mechanism as an integral component of mixed-initiative scaffolding.

### **Mixed Initiative Interaction**

Mixed-Initiative Interaction (MII) is a naturally-occurring feature of human interactions. Mixed Initiative (MI) Interaction [2][14] comprises a new set of methodologies that propound the need for independent initiative taking to assume control of the conversation within the context of discussion. The motivation behind our research is to capture the process of this natural phenomenon and deduce reasons for interactions initiated by the system. Mixed-initiative systems exhibit various degrees of involvement in regards to the initiatives taken by the user or the system. In any discourse, the initiative may be shared between either, a learner and a system agent, or between two independent system agents. Both the parties in question establish and maintain a common goal and context, and proceed with an interaction mechanism involving initiative taking that optimizes their progress towards the goal. One of the key elements for successful mixed-initiation is the ability of the system to recognize opportunities for mixed-initiative interactions.

Our system initiates interactions that are based on the principles of Self-Regulated Learning (SRL) in online learning depending on the learners' progress in the domain. SRL is a theory that concerns how learners develop learning skills and how they develop expertise in using learning skills effectively. SRL comprises a set of strategies and tactics employed by learners to regulate their own learning processes. It arises from two key observations. First, learners' goals for learning take precedence over goals set by teachers, authors of curricula, and developers of learning objects. Second, learners are in charge of how they learn. They choose which study tactics and learning/composing/problem-solving strategies to use as they strive to achieve their goals. Research shows learners often set unsuitable goals, have a limited repertoire of learning skills, often do not use learning skills they have, and frequently need extensive help to manage learning and collaborative tasks. These provide the opportunities for system-initiated interaction. In MI-EDNA, opportunities for mixed-initiative interactions are recognized based on the sequences of strategies and tactics used by the learners. The system observes the fine-grained interactions of the user with the online material, translates such interactions into coarse-grained strategies and tactics, recognizes patterns of usage of strategies and tactics, matches these patterns against the optimal strategies and tactics prescribed by

SRL, and triggers system-initiated interactions to scaffold the learner who has strayed away from optimal SRL strategies.

In many earlier systems the control of the discourse was granted to one agent, be it the learner or the system [6][5] or alternatively, a passive listener was created [7] who does not assume control. To overcome the mechanistic methodologies adopted in the design of such systems mixed initiative interactions are incorporated in many interfaces which allow for either agent (human or the system) to interrupt and take the initiative in a discourse or a dialogue. This is similar to the way that humans often asynchronously assume control of the conversation while speaking within the context. Seeing the growing importance given to mixed initiative dialogues, developing models using mixed-initiatives has become critical to environments where learners interact intelligently with a system [10].

An MI based mechanism would thus be ideal in order for a system agent to monitor the progress of a learner who is engaged in the learning environment and present periodic recommendations to the learner while establishing a relevant context that could prove helpful to the learner for self-regulation. We mimic such mixed-initiative behaviour of the system agent using a production rules.

### **ENCODING SCAFFOLDS IN MI-EDNA**

We have modeled a few scaffolding tactics and strategies in MI-EDNA based on the scaffolding/fading techniques addressed in [3] and [17]. Scaffolding encourages learners to plan their learning process, to monitor their emerging understanding, to use different strategies to learn, to handle task difficulties and demands, and to assess their emerging understanding in comparison with other learners. In essence, MI-EDNA helps a learner to self-regulate as well as to co-regulate with fellow learners.

In most tutoring systems, it is easy for a learner to lose interest in learning and leave the computer without the consent from the tutoring systems [12]. Research also shows that novice and weaker learners fare better in highly structured programs with high system intervention while advanced learners with higher ability are better judges of their own need for system help and intervention [1]. Therefore, in order to obtain better tutoring outcomes, a tutoring system should emphasize effective engagement of learners in the learning process and be adaptive to each individual learner.

The scaffolding mechanism discussed in the context of MI-EDNA has the ability to dynamically adapt to most learning patterns. We contend that adding a degree of motivational discourse to the entire dialogue would gain and sustain the learner's attention, provide learning experiences and offer a satisfying experience by boosting the learner's confidence.

MI-EDNA obtains a large base of learning patterns from interactions of learners when they use the gStudy system

[18]. gStudy provides a framework for active online learning that allows learners to self regulate their learning process. It presents domain-specific kits that consist of organized collections of connected learning material. The learners engage in various learning activities within gStudy including marking, highlighting paragraphs, note taking, online help, compiling, composing, and so on. These interactions along with the domain specific knowledge of the kit in current use are comprehensively monitored and recorded in interaction logs. The interaction logs are then parsed and instantiated into the ontology in MI-EDNA for use as a knowledge base for the application of the rules. MI-EDNA uses this knowledge base to recognize patterns of tactics and strategies enacted by the learners. Our rule based system, as a subset of the MI-EDNA system, operates on this instantiated ontology to obtain a set of facts that capture the current interactions of the user with the gStudy system. The production rules match the tactics and strategies adopted by learners to specific phases and variables of SRL. The production rules also peer into the meta-data associated with the domain-specific kit of gStudy that is currently in use by the learner and use the information obtained to ascertain the current topic under study. The topic under study coupled with the learner strategies captured in the instantiated MI-EDNA ontology are used to establish a context for providing learning scaffolds. Once the context of current interaction has been established, the production rules decide on appropriate feedback. The degree of system initiated interaction is also monitored and closely matched to the level of self-regulation exhibited by the learner in question. The amount of scaffolding and regulation required by learners varies and so the system engages novice users in a more structured manner, frequently interacting with them to help them adopt the SRL mould. Advanced learners on the other hand are subjected to weaker and more flexible manners of interaction which allow for much greater levels of user freedom. Also, a fading mechanism is proposed as part of the final system which would oversee the transition of novice learners into more advanced moulds and correspondingly fade out the degree of scaffolds provided. Currently our research direction involves implementing the rule set for the MI-EDNA system. We have finished with a preliminary identification of the domains of scaffolding for MI-EDNA and the specification of the rule set. We are currently proceeding with integrating the scaffolding rule set with the MI-EDNA mixed-initiative interaction mechanism and are planning for an eventual integration with the gStudy system.

Different domains require specific types of scaffolding to varying degrees. In the next section we identify the three domains that we address in MI-EDNA and highlight how we customize the scaffolds based on the principles of SRL.

## Domains in MI-EDNA

Scaffolds are customized to the needs of each learner and are presented to the learner at opportune times when the system chooses to initiate an interaction. The scaffolds contain cognitive and/or meta-cognitive feedback. This also promises to ease the transformation of their study strategies to incorporate self-regulatory mechanisms.

We contend that online learning using gStudy and MI-EDNA helps learners converge towards optimal SRL strategies. However, in a pool of a large number of learners, it is often noted that some learners do not converge towards optimal SRL strategies due to failure to represent, recognize, regulate, and react to their learning process. Overall, studies indicate that highly self-regulating learners tend to outperform the rest in hypermedia environments [4].

The interactions of the user with gStudy pose a wide ranging test-bed for implementing the recommendation mechanism that would help ease the transition of learners from a conventional approach to one based on SRL strategies and at the same, embedding motivation within the superstructure.

In order to meet our goal of providing SRL-based scaffolds, MI-EDNA bases its recommendations on the type of interaction mode that the user is currently using:

- **Reading Mode:** This mode implies an interaction process where learners are engaged in reading-oriented tasks using the gStudy system. The learners work with a learning-kit that is specially created for a given domain of knowledge. The reading processes involve interactions such as browsing, highlighting and making notes. The system captures the reading interactions of the learners and tracks the self-regulation strategies enacted by them. The interactions captured while operating in the reading mode are based on the processes and strategies that learners choose to adopt while using the learning-kit opened in the gStudy system. Once these logged interactions are instantiated into the ontology, a set of preliminary facts is generated for the rules to base their firing sequence upon. On the basis of this information, scaffolds are generated by the firing of rules in a certain sequence. The system then takes the initiative to provide these scaffolds to the learner. Table 1 shows a sample mixed-initiative reading interaction between a learner<sup>1</sup> and the system in the Reading mode.

**Table 1 - Sample Learner-System Reading Interaction**

Learner	<begins a reading session>
Learner	Browses the web page
Learner	Highlights a paragraph
Learner	Highlights a paragraph

<sup>1</sup> A rather obedient and compliant learner!

Learner	Highlights a paragraph
System (Takes Initiative)	<at this time the system takes initiative to suggest feedback> It appears that you have highlighted the content 3 times. May I suggest that you take notes corresponding to your highlights?
Learner (Takes Initiative)	<reverts back to the last highlight and creates a note of type 'Important' on the highlight (without elaborating the importance of the highlight)>
System (Takes Initiative)	May I suggest adding a brief paragraph describing the context for the note for future reference?
Learner	<adds a paragraph explaining why the highlighted text is important>
Learner	<highlights a paragraph, and makes an 'Important' note with elaboration>
Learner	<highlights a paragraph, and makes an 'Important' note with elaboration>
System (Takes Initiative)	It appears that you feel comfortable making 'Important' notes, may I recommend also exploring other types of notes in the future. For example 'Critical Detail' and 'Significant Study'.
Learner	<changes previous 'Important' note to 'Critical Detail'>
Learner (Takes Initiative)	How is the 'Important' note different from a 'Critical Detail' note?
System	<explains the difference between the notes>
Learner	<highlights a single word>
System (Takes Initiative)	In addition to taking notes, you may also define names for the glossary and define concepts.
Learner (Takes Initiative)	How do I access the glossary after I define a name?
System (using gEliza <sup>2</sup> )	You could toggle the drop down menu in between the table of contents and the kit details at the left of the browsing screen. Selecting 'Glossary' will let you view it.
Learner	<continues with work>

- **Composition Mode:** Our system can also present the learner with a series of composition exercises. To start with, the system acquires a context for interaction from the usage patterns of the learner that are instantiated in the composition domain ontology. Then, the system

<sup>2</sup> A dialogue-based help system that is modeled after the famous Eliza (from the literature of Artificial Intelligence)

engages the learner in devising a composition plan. Later, the system tracks the development of the composition as reflected in the ontology with more interaction details. The structural validity is inspected with respect to the plan as well as with respect to the requirements of the exercise. The system takes initiative when learners deviate from the plan or the requirements. Initiatives originating from the system concentrate on helping the learner identify strategies to refine his/her form of expression and organize his composition as per the plan and the requirements. Table 2 - Sample Learner-System Writing Interaction. Table 2 shows a sample writing interaction between a learner and the system.

**Table 2 - Sample Learner-System Writing Interaction**

Learner	<starts a composition session by selecting and modifying a composition plan (structural outline) from a list of plans presented by the system>
System (Takes Initiative)	In addition to a composition plan, a good composition would benefit from the development of a concept map.
Learner	<takes some time revising the composition plan and generating a concept map>
Learner	<starts to write the essay by typing a long paragraph of text>
System (Takes Initiative)	Is the paragraph too long?
Learner	<splits the long paragraph into multiple short paragraphs; continues with the action in the composition plan>

- **Problem-solving Mode:** gStudy and MI-EDNA can also engage learners in problem-solving activities. Presently, the system captures the interactions of the learner who is writing Java-based programming code. We are currently working to include a built-in IDE<sup>3</sup> to write, compile, and debug Java programs within the system. The IDE would support interactive compile time feedback based on the production rule set for the domain. The system would take the initiative at compile time and base its scaffolds on the syntactic and structural errors in the composition of the program. **Table 3** shows a sample problem-solving interaction between a learner and the system.

**Table 3 - Sample Learner-System Problem-Solving Interaction**

Learner	<starts a Java Programming session>
Learner	<writes five lines of code without internal

<sup>3</sup> Integrated Development Environment for Programming

	documentation>
Learner	<compiles the code>
System (Takes Initiative)	You are missing: 1) inclusion of system libraries and 2) internal document that helps in planning the code. I also think that you are compiling too soon.
Learner	<writes more code; includes the required class libraries; forms templates for the user-classes as part of the internal documentation>
Learner (Takes Initiative)	Compiles the program again.
System (Takes Initiative)	Good! Are we self-regulating or what! Another good strategy in coding is to <...>

These interactions highlight the importance of SRL-oriented scaffolded feedbacks and how they possibly influence the learning process. Even though the interactions look superficial, we believe that most novice learners would benefit from such scaffolded mixed-initiative interactions to improvise their self-regulatory skills.

## CATEGORIES OF SCAFFOLD FEEDBACKS

Among the various scaffolding techniques that we have observed in the literature, we are focussing on the following five categories of scaffold feedbacks as shown in Table 4. They are:

- *Content Scaffolds* are based on the content that the learner is currently interacting with in a session. For instance, the system can help the learner set long-term and short-term goals.
- *Process Scaffolds* guide the learner to monitor his/her learning processes. For instance, the system can assist the learner in formulating a learning strategy and trace the learner activities with respect to the strategy.
- *Learner Knowledge Scaffolds* are based on the subject knowledge of the learner as modeled by the system.

**Table 4. Categories of Scaffold Feedbacks**

Categories	Sample System Scaffold Initiation Opportunities	Rules example	Tactic/Strategy Suggested
Content Scaffolds	Goal setting strategy suggestions	The system evaluates the topic under study and helps the learner form a set of short- and long-term goals.	Goal Formation
	Providing reference material	The system provides sources of information that are relevant to the set of goals established for the given content.	Goal Oriented Resource Identification
	Help learner focus attention on important sections	If the learner takes <b>notes only on certain topics</b> , then system recommends <b>other document locations</b> that are linked to the same topic, which the learner may not be aware of.	Linked Resource Identification

For instance, based on the recent quiz results, the system can advise the learner to review specific sections of the content.

- *Normative Scaffolds* place their emphasis on the norms established by other learners in group-study or classroom settings. The feedback offered here is expected to help a learner learn by emulating the tactics of others. For instance, learners may wish to query the system to reflect on the best reading practices of a fellow learner who consistently scores top grades in the class. Based on this reflection, the system may revise the reading strategy for the learner.
- *Context Scaffolds* offer standardized Knowledge of Correct Response (KCR) [13] where the system provides relevant information when it is aware of the information required by a learner in response to his/her interactions. For instance, when the learner does not understand a particular word with respect to a reading task, the system can provide related information from the glossary or the concept map.

In order to present the scaffold feedback, the system recognizes opportunities to take the initiative from the learner. We choose to implement the scaffolds using a rule based system because of the inherent flexibility that is imparted by them. Our production rule system provides a basis for easy representation of the interaction features in the form of facts allowing multiple aspects of interaction (as multiple facts) to influence the firing of a rule. Beyond simply checking for a specific interaction feature, the firing of a rule based on multiple interaction facts helps the system easily analyze the user's process to determine whether the user is making errors that might be corrected through task analysis and scaffolding. Rules also do not require training data, unlike most probabilistic methods of analysis and are thus less prone to the characteristically individually unique nature of human interaction. Thus production rules provide an ideal vehicle to be able to analyze the variables of SRL and form scaffolds on their basis. Table 4 presents a detailed view of the scaffold feedbacks.

		If the learner makes a ' <b>question</b> ' note and if an answer appears nearby or has been identified in the learning material, then the related topic is presented.	Linked Knowledge Collation
		If a majority of learners spent a considerable amount of time reading a section, then associate the speed of reading with the corresponding content and the performances of learners in evaluation exercises related to that content.	Collaborative Emulation
	Based on the learner's interaction, the system can guide him/her specific SRL tactics	If the learner is only <b>highlighting</b> , then the system recommends the use of <b>taking notes</b> to the highlighted text.	Self Study Improvement Tactics
Process Scaffolds	Reminders for incomplete tasks	If the learner takes notes but doesn't write anything in the notes, the system recommends filling in short descriptions to help the learner recall.	Self Study Improvement Tactics
		Students may be prompted to go back to ' <b>question</b> ', ' <b>to do</b> ', ' <b>don't understand</b> ' and ' <b>debate</b> ' notes on which they have not elaborated.	Task Recollection
	After observing the structural details of learner compositions, standardization may be suggested	If a learner tries to write an essay as one long paragraph then prompt the learner to follow a standard pattern or template.	Written Structural Standardization
Learner Knowledge Scaffolds	System compares results of learner interactions with goals	System evaluates learning outcomes and compares the progress with respect to the established goals, giving a performance appraisal.	Goal Based Evaluation
	The system provides feedback on the learner's current knowledge level	The system can show the <b>learners' knowledge status</b> based on the learner's model.	Progress Level Reflective Motivation
Normative Scaffolds	Based on peer interactions and accomplishments, the system can initiate comparative accomplishment statistics	The system shows the learners their standings in regards to the score or the learning style with respect to their peers.	Comparative Motivation
Context Scaffolds	Context-Based Help	If the learner highlights a word and makes a 'Don't Understand' note then the system searches in the Glossary for that word and then provides the reference to the learner.	Knowledge of Correct Response

## CONCLUSION

MI-EDNA represents the scaffold feedbacks in terms of production rules. Using a rule based inference mechanism for scaffolding paves way to build a dynamic and robust interactive system that offers recommendations based on the asynchronous actions of the learner. Thus, inherently the system gains a *degree of initiative taking*<sup>4</sup>, albeit still dependent on the actions of the learner. The calculation of the *degree of initiative taking* corresponding to a set of interactions determines the fading effect (systematic and graceful degradation of support) of the system with respect to the requirements of the learner.

Presently, our work focuses only in recognizing tactics enacted by the learners, envisage the underlying strategy that spawned the tactics, and recognize opportunities for

the delivery of SRL-based feedback. In summary, MI-EDNA observes the fine-grained interactions of the learner with the online material, populates these interactions in an ontology, automatically translates these interactions into fine-grained tactics, predicts the coarse-grained strategies, matches these observed tactics and strategies against the optimal tactics and strategies prescribed by SRL, triggers system-initiated interactions to prompt and guide the learner who has strayed away from optimal SRL tactics and strategies, enables a logic-based query interface for learner-initiated interactions, develops a cognitive model of skills of the learner, and attempts to revise the ontology based on the model.

The gStudy project has already shown promise with initial student trials which suggest that it would be highly beneficial to their learning process [8]. We believe that rule based systems help achieve better interoperability between various knowledge domains and allow operations on different knowledge representations. Some of the research directions that are open to future research include a) knowledge engi-

<sup>4</sup> Currently, the degree of initiative taking is dependent on the frequency of opportunities for system initiations and the importance of the category of the scaffold feedback.

neering of applied educational psychology domains such as reading, composition and problem-solving, b) a model of the self-regulatory capabilities of learners, c) an evaluation of the influence of mixed-initiative interactions and interfaces, d) the development of a cognitive model of the self-regulatory skills of the learner, e) employing MI-EDNA for co-regulated learning, f) the verification and validation of the underlying SRL model based on the cognitive model, g) providing a common ontological SRL framework for geographically distributed learners and instructors in a blended online learning environment, g) explanation-aware SRL modelling and scaffolding and h) a study of the effect that actively provided scaffolds, based on the context established, would have on the cognitive load of the learner.

## ACKNOWLEDGMENTS

I would also like to acknowledge with the gratitude the contribution of the LORNET research group for my funding and the gStudy group for involving me with their research.

## REFERENCES

- [1] Aleven. V, Koedinger. K. R, Limitations of student control: Do students know when they need help? *Proceedings of the 5th International Conference on Intelligent Tutoring Systems, ITS 2000*, 292-303, Springer Verlag, 2000.
- [2] Allen J. F, Mixed-initiative interaction, *IEEE Intelligent Systems*, pages 14-16, September 1999.
- [3] Azevedo, R., Cromley, J. G., Seibert, D., & Tron, M. The role of co-regulated learning during students' understanding of complex systems with hypermedia. *Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL*, April, 2003.
- [4] Azevedo, R., & Cromley, J.G., Does training on self-regulated learning facilitate students' learning with hypermedia? *Journal of Educational Psychology*, 2003.
- [5] Boicu, M. Tecuci1, G. Marcu1, D. Boicu, C.Stanescu, B. Mixed-initiative Control for Teaching and Learning in Disciple. *Proceedings of the IJCAI-03 Workshop on Mixed-Initiative Intelligent Systems*, Acapulco, Mexico, August 2003.
- [6] Cohen. P. R, The pragmatics of referring and the modality of communication. *Computational Linguistics*, 10:97-146, 1984.
- [7] Cohen. R, Analyzing the structure of argumentative discourse. *Computational Linguistics*, 13:11-24, 1987.
- [8] Hadwin, A. Nesbit, J. Jamieson-Noel, D. Winne, P, Kumar, V. Tracing self-regulated learning in an e-learning environment. *AERA05*. Montreal. April 2005.
- [9] Körndle. H, Narciss. S, Proske. A, Promoting self-regulated learning in web-based learning environments. *Instructional design for multimedia learning*. Münster Waxmann, October 2002.
- [10] Lester, J. C., Stone, B. A., and Stelling, G. D. 1999. Lifelike Pedagogical Agents for Mixed-initiative Problem Solving in Constructivist Learning Environments. *User Modeling and User-Adapted Interaction* 9, 1-2, 1-44, January 1999.
- [11]Ley. K, Motivating the Distant Learner to be a Self-Directed Learner. *20<sup>th</sup> Annual Conference on Distance Learning and Teaching, University of Wisconsin*, July 2004.
- [12]Li. X, Soh. L. K, A Literature Review on Learner Control Strategies in Software Tutoring Systems. *Technical Report TR-UNL-CSE-2003-6*, Department of Computer Science and Engineering, University of Nebraska-Lincoln, Lincoln, NE., June 2003.
- [13]Narciss. S, The impact of informative tutoring feedback and self-efficacy on motivation and achievement in concept learning. *Experimental Psychology*, 51(3), 214-228, 2004.
- [14] Ramakrishnan, N. Capra, R. P´erezQui, M. Mixed Initiative Interaction = Mixed Computation. *Proceedings of the 2002 ACM SIGPLAN workshop on Partial evaluation and semantics-based program manipulation*, Volume 37 Issue 3, January 2002.
- [15]Winne, P. H. Self-regulated learning viewed from models of information processing. In B. J. Zimmerman & D. H. Schunk (Eds.), *Self-regulated learning and academic achievement: Theoretical perspectives (2nd ed., pp. 153-189)*. Hillsdale, NJ: Erlbaum, 2001.
- [16]Zimmerman, B. Becoming a Self-Regulated Learner: An Overview. *Theory into Practice*, Volume 41, Number 2, Spring 2002.
- [17]Wenger, E. *Artificial Intelligence in Tutoring Systems*. Morgan-Kaufman, California, 1987.
- [18]Winne P.H., Nesbit J.C., Kumar V.S., Hadwin A.F., Supporting Self-Regulated Learning with GStudy Software: The Learning Kit Project, *International Journal of Technology, Instruction, Cognition and Learning* (accepted for publication), 2005.