

# Recognizing Opportunities for Mixed-Initiative Interactions based on the Principles of Self-Regulated Learning

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## Abstract

Successful mixed initiative systems employ mechanisms that explicitly recognize opportunities for initiatives among the system and the users. In this paper, we propose a theory based framework, founded on the principles of Self Regulated Learning, that recognizes strategies and tactics learners used in their interactions. These interactions are observed from within gStudy, a learning tool that students use as part of learning activity. Production rules encode SRL-specific knowledge in an OWL-based formal ontology and JESS is used as an inference engine to recognize strategies and tactics used by learners in specific reading and problem-solving activities. Using such inferences we demonstrate how the system recognizes opportunities for mixed-initiative interactions to guide learners who veer away from optimal SRL strategies.

## Introduction

Mixed-Initiative Interaction (MII) is a naturally-occurring feature of human interactions. The motivation behind our research is to capture the process of this natural phenomenon and deduce reasons for interactions initiated by the system or the user. Mixed-initiative systems exhibit various degrees of involvement pertaining to the initiatives taken by the user or the system. One of the key elements for successful mixed-initiation is the ability of the system to recognize opportunities for initiatives based on well-founded theoretical principles. In this paper, we propose a framework based on the principles of Self-Regulated Learning (SRL) (Winne 1997, Zimmerman 2002) to formally recognize opportunities for mixed-initiative interaction in the domain of Reading in online learning environments.

We developed a mixed-initiative interaction (MII) framework modeled after pair-programming<sup>1</sup> (Williams & Kessler 2003) where the system plays the role of a more experienced partner and initiates interaction with the learner as dictated by the model. In a similar approach, our system initiates interactions that are based on the principles of Self-Regulated Learning (SRL) in online learning depending on the learners' progress.

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/problem-solving strategies to use as they strive to achieve their goals. Normally, learners set unsuitable goals, have a limited repertoire of learning skills, 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 our work, 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 prompt and guide the learner who has strayed away from optimal SRL strategies.

Many of the earlier systems involving human-computer interactions were built as question-answer systems where the initiatives are pre-determined, thus factoring out the role of mixed initiatives. This led to the allocation of control to one participant (the user or the system) (Cohen 1984, Burstein et. al 2003, Boicu et. al 2003), or the creation of a passive listener (Cohen 1987). A number of mixed-initiative systems have been developed based on the notion of 'allocation of control' (Allen 1999, Marek & Druzdzel 1999, and Guinn 1997).

There are systems that toggle the control to initiate interactions based on the competency of either the user or the system to complete the task at hand. For example, a mixed-initiative interaction interface for online website development was described by Perugini and Ramakrishnan (2003) that allowed users to specify personalization aspects out of turn to the system, allowing the system to modify the webpage to the needs of the user as and when required. Levels of mixed-initiative control have been defined

<sup>1</sup> <http://www.extremeprogramming.org/rules/pair.html>

according to when the user or the system chooses to initiate a change in the dialogue pattern (Allen 1999).

Good evaluations of mixed-initiative dialogue and initiative taking mechanisms have been presented by Guinn (Guinn 1999). Systems with suggestion based mechanisms for transfer of control have been also found useful in building mixed initiative interactions (Gupta 2003).

Our work is unique and distinct from the current approaches in the sense that the opportunities for initiatives are explicitly recognized based on SRL, a seminal theory in education psychology, and both the system and the learner can explain why a particular interaction has been initiated.

Strategies and tactics in our domain are represented in the form of ontology (Kumar et. al 2004). We promote ontology as a solution to formally represent the principles of educational theories. The ability to recognize sequences of strategies and tactics in learner interactions with the system and the ability to match these patterns against SRL-prescribed patterns of strategies and tactics have been represented as Production Rules in JESS<sup>2</sup>.

We will present a brief introduction to the domain model that consists of the theory of Self-Regulated Learning (SRL) and identify some of the principles of SRL that we intend to formally capture. We will present the architecture of our system named MI-EDNA, highlight the salient features of our ontology and outline how we recognize SRL-oriented tactics and strategies. We will follow it up with a discussion on how to recognize opportunities for system-initiated interactions using a rule-based approach.

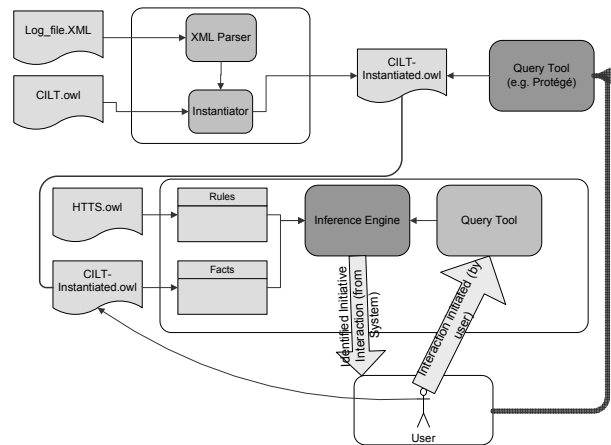
### Architecture of MI-EDNA

The architecture is geared towards addressing our goals of enabling both the system and the learner to be able to explain why a particular interaction has been initiated and how such opportunities have been recognized based on the principles of SRL. The architecture promotes a modular and adaptable system design since the rules and facts can be fed into the system in an ontological format and reasoned with, at run time. Our architecture for SRL-based mixed-initiative interaction is presented in Figure 1.

The LearningKit Project<sup>3</sup> aims to develop a study tool – gStudy - for reading, writing and problem-solving activities. gStudy allows the learner interactions to be captured and analysed to recognize tactics and strategies that students use to reach their goals during the learning process as described by Winne (2001). Hadwin et al (2005) outline some of the generic strategies and tactics students used in the domain of Reading. Kumar (2004) identifies

some of the means to recognize strategies and tactics employed in computer programming.

Figure 1 – System Architecture



We developed an instantiation mechanism that maps the log of trace data of learner interactions captured within gStudy onto ontology. The log data consists of interactions including browsing, highlighting, compiling code, text chatting, indexing, concept mapping, note taking, reviewing, collaborating, and so on. Information pertaining to these types of interactions is automatically instantiated in our ontology.

### Ontological representation

The use of ontology as knowledge representation and knowledge sharing mechanism is a century-old notion. It has been extensively employed in the domain of online learning environments in the past decade. The use of ontology for course authoring, knowledge engineering, ontology instantiation has been an area of ongoing research (Aroyo et. al 2002, Dicheva et. al 2003, Mizoguchi et. al 1996). Ontology is a powerful knowledge representation scheme that can describe a vast range of complex systems using simple relations.

In our research, we have used the ontological representation of the domain knowledge and the interaction knowledge primarily because ontology allows for a formal representation of concepts and the relationships between them. The formalism that we use is based on Description Logic as formulated in OWL-DL<sup>4</sup>. Our TTS (teaching tactics and strategies) ontology formally captures SRL-specific teaching tactics and strategies. Some of these tactics and strategies are presented in Figure 2.

<sup>2</sup> Jess is a generic rule based inference tool.

<http://herzberg.ca.sandia.gov/jess/>

<sup>3</sup> <http://www.learningkit.sfu.ca>

<sup>4</sup> <http://www.w3.org/TR/owl-guide>

**Figure 2 - Excerpt from the Teaching Tactics and Strategies Ontology (OWL file)**

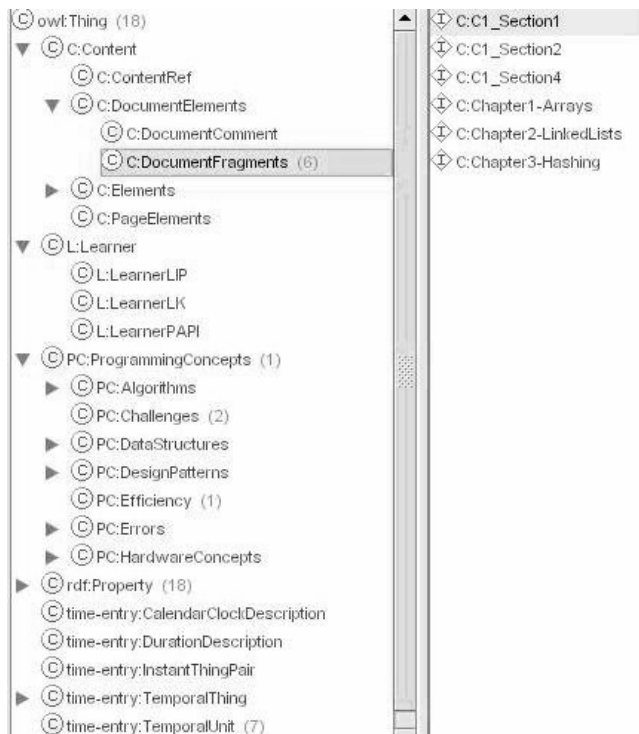
```

</owl:Class>
<owl:Class rdf:about="#SRLSelfReflectionPhase">
  <owl:disjointWith>
    <owl:Class rdf:about="#SRLPerformancePhase">
      </owl:disjointWith>
    <rdfs:subClassOf>
      <owl:Class rdf:about="#SelfRegulatedLearningET"/>
    </rdfs:subClassOf>
    <owl:disjointWith rdf:resource="#SRLForeThoughtPhase"/>
  </owl:Class>
<owl:Class rdf:about="#EvaluationTT">
  <owl:disjointWith rdf:resource="#IndependentSeatWorkTT"/>
  <owl:disjointWith>
    <owl:Class rdf:about="#SummarizingTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#IdentifyingNewConceptsTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#FeedbackShowingGrowthTT"/>
  </owl:disjointWith>
  <owl:disjointWith rdf:resource="#QuestionsTT"/>
  <owl:disjointWith>
    <owl:Class rdf:about="#ClusteringTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#OutliningTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#TransitionTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:Class rdf:about="#MakingDecisionTT"/>
  </owl:disjointWith>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
    >evaluates self by reflecting, reviewing or attempting the quizzes</rdfs:comment>
  <owl:disjointWith>
    <owl:Class rdf:about="#PerformanceImprovementTT"/>
  </owl:disjointWith>
  <owl:disjointWith>
    <owl:disjointWith>

```

The TTS ontology enables us to track the SRL variables and SRL phases. Presently, MI-EDNA represents and reasons with two SRL models – Zimmerman’s three phase model (Zimmerman 2002) and Winne and Hadwin’s four phase model (Winne & Hadwin 1998).

**Figure 3 – Excerpt of CILT ontology**



In addition to TTS, MI-EDNA uses an application ontology named CILT (Content-Interaction-Learner-Time). This ontology, represented in OWL-DL format, captures the essence of the learner’s interaction of the content at any given time. An excerpt of the CILT ontology is shown in Figure 3.

Recognizing interactions at finer levels, such as highlighting, linking, creating summary note, creating concept notes, browsing and matching these interactions to tactics and strategies at the coarser levels (Winne et. al 2005) enables the system to map learner interactions onto SRL models. These mappings form an integral component of the conditions in the production rules. The system relies on these rules to recognize initiative opportunities and prompt feedback to learners during the learning process.

### Recognition of initiative opportunities

In the pair programming model, the expert is mainly an observer with open-ended opportunities to initiate interaction. There are no specified cases or specified situations for the expert to initiate interaction. The interaction is mostly dependent on the expert programmer and the knowledge level of the novice (Jensen 2003). In an analogical approach, our system **passively observes** learner interactions, **recognizes opportunities** for initiatives, and **actively initiates** interactions that are based on the principles of Self-Regulated Learning.

To **passively observe** learner interactions we need to instantiate the ontology with learner interactions. Manual instantiation of ontology is tedious, cumbersome, and error prone. Ideally, ontologies should be instantiated in an automated fashion. However, not many systems have been designed to fully automate instantiation of the underlying ontologies. We are successful in accomplishing automatic and semi-automatic instantiation of ontologies in MI-EDNA. For instance, the online contents for Java Programming have been developed and tagged using DocBook<sup>5</sup> platform. We then used a script to convert the tagged content into the corresponding OWL format. The learner interaction instantiations, however, are fully automated. As learner interactions are logged in a file, in parallel, the real time interaction data is also fed into the instantiator that populates the ontology with concepts and relations.

Once the learner interactions are instantiated in the ontology, they provide the basis for the facts in the JESS inference engine. MI-EDNA uses these instantiated interaction data to recognize patterns of tactics and strategies enacted by the learners. The production rules match the tactics and strategies to specific phases and variables of the SRL models. Further, the production rules decide on appropriate feedbacks.

<sup>5</sup> www.docbook.org

The opportunities for initiative are recognized based on the principles of SRL regulated by the scaffolding/fading techniques. When learners read or solve problems, research indicates that they can benefit by having access to feedback about

- (a) Guidance to learners on navigation of content (content feedback),
- (b) Methods they use to study/solve problems (process feedback),
- (c) How much they have learned (knowledge of results),
- (d) How learner’s peers study and what they score on tests (normative feedback), and
- (e) Supporting learners based on the context of interaction (context feedback).

gStudy logs fine-grained data about the interactions pertaining to these types of feedback. We can mine this data to deliver these feedbacks to learners when it is appropriate. MI-EDNA responds to queries that a learner poses as well as initiates interactions with the learner based on these feedbacks about domain topics and SRL-specific strategies and tactics.

MI-EDNA has two distinguishing features. First, system-initiated queries and responses are based on data that gStudy gathers on the fly. For instance, a student can inquire about the number of times she has reviewed a glossary term in a session where she studied technical material. Second, the topic of queries can be about the content and about study tactics as traced by gStudy when learners studied the content. For example, a learner will have tools to build complex queries, such as i) what percent of students in his/her class highlight text, ii) immediately make a note, iii) link that note to relevant glossary items, and iv) score more than 85% on the test covering the assignment, in that order.

Our system is designed to recognize opportunities and initiate interaction with the learners in the context of the five identified feedbacks. Examples of these feedbacks are shown in Table 1.

SRL based initiative 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, by **actively initiating** interactions MI-EDNA helps a learner to self-regulate as well as to co-regulate with fellow learners.

Categories	Sample System Scaffold Initiation Opportunities	Tactic/Strategy Suggested
Content feedback	• Goal setting strategy suggestions	Goal Formation
	• Providing reference material	Goal Oriented Resource Identification
	• Help learner focus attention on important sections	Linked Resource Identification
		Linked Knowledge Collation
		Collaborative Emulation
• Based on the learner’s interaction, the system can guide him/her specific SRL tactics	Self Study Improvisation Tactics	
Process feedback	• Reminders for incomplete tasks	Self Study Improvisation Tactics
		Task Recollection
	• After observing the structural details of learner compositions, standardization may be suggested	Written Structural Standardization
Learner Knowledge feedback	• System compares results of learner interactions with goals	Goal Based Evaluation
	• The system provides feedback on the learner’s current knowledge level	Progress Level Reflective Motivation
Normative feedback	• Based on peer interactions and accomplishments, the system can initiate comparative accomplishment statistics	Comparative Motivation
Context feedback	• Context-Based Help	Knowledge of Correct Response

**Table 1 - Examples of system initiation opportunities for gStudy, based on the five feedback categories**

In MI-EDNA, we recognize the opportunities when exactly the system (or the users) should take control of the interaction and the initiator is in a position to provide explanations. Some of the production rules that characterize MI-EDNA’s ability to recognize opportunities for initiative-taking are listed in Table 2.

<b>Sample Production Rules</b>
If the learner takes notes only on certain topics, then system recommends other document locations that are linked to the same topic, which the learner may not be aware of.
If the learner makes a 'question' note and if an answer appears nearby or has been identified in the learning material, then the related topic is presented.
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.
If the learner is only highlighting, then the system recommends the use of taking notes to the highlighted text.
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.
If a learner tries to write an essay as one long paragraph then prompt the learner to follow a standard pattern or template.
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.

**Table 2 – Sample production rules that recognize opportunities for mixed-initiatives**

Explicitly recognizing opportunities for initiatives by the system or by the user is imperative to the success of mixed-initiative systems. Employing production rules to recognize opportunities for initiatives based on well-founded theories, MI-EDNA is able to formally ground and analyze learner-system interactions.

## Conclusion

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 prompt and guide the learner who has strayed away from optimal SRL strategies.

Our work is based on the use of ontology based knowledge representation and reasoning to identify opportunities in a mixed-initiative environment. System-initiated interactions are aimed at content, process, knowledge, normative, and context feedback.

The system can initiate interactions with the learner to promote specific strategies and tactics with respect to the content and/or the context. It can also initiate interactions with the learner when it finds gaps in learner strategies and

tactics. Further, it can initiate interactions with the learner with respect to the strategies and tactics employed by other students. Using these five recognizable opportunities, we provide contextualized feedback to learners, on the fly, as they study or solve problems in specific learning activities. Our research collects data on how such explainable and theory-oriented prompting and feedback promote significant, transferable, and enduring changes to learner study skills and problem solving abilities.

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