Towards a Cognitive Model to Support Self-Reflection
Emulating Traits and Tasks in Higher-Order Schemata

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Abstract. Metacognitive modeling has begun to play an increasingly important role in adaptive eLearning to support learning and self-regulating processes. It is essential that students learn to regulate their learning through self-reflection by acquiring monitoring and pro-active strategies. The ETTHOS model currently estimates the metacognitive state of the learner by modeling both metacognitive awareness and a cognitive activity model. This model represents the traits and tasks that are complimentary to learning, in a way that allows for logical separation between the modeling process and the learning environment. The model, its application, and its implications for individual and collaborative reflection are presented here.

Keywords: Educational Technology, Adaptive eLearning Systems, User Modeling, Metacognition, Self-Reflection

1 Motivation – Modeling Cognitive Traits and Tasks

An understanding of the mental activities and functions through which successful learners acquire and process knowledge continues as a goal of psychologists, educators, and more recently developers of learning systems [1][2][3][4]. Adaptive eLearning research is currently interested in learner characteristics such as affect, self-regulated learning strategies and metacognition. Metacognition [5] refers to the complimentary psychological functions that actively monitor and consequently regulate cognitive functioning according to the current state of an individual. Metacognitively aware learners reflect on their progress towards learning goals. They can perform better than unaware learners, as they have access to strategies that allow them to plan, organize and monitor their learning [6]. One key challenge for cognitive modeling is the link between these abstract processes and explicit interactions within learning environments. This can be inferred through questioning [2], making inferences about conversations [1], or via emotional cues through a video camera [3].

This paper outlines the ETTHOS (Emulating Traits and Tasks in Higher-Order Schemata) Model [4], a model for supporting individual reflection of metacognitive awareness. ETTHOS provides an alternative approach to modeling learner cognition. It represents latent cognitive characteristics in a measurable way, and contributes to the emerging field of adaptive metacognitive systems, by supporting loose coupling with eLearning systems. ETTHOS is currently implemented in the Goby service.
Goby [4] is delivered as a separate service that is loosely coupled with an adaptive eLearning system. The metacognitive state of the learner is inferred via dialog (prompts and questions) interactions. This dialog prompts the learner to reflect on their metacognitive processes. The structure of Goby’s cognitive trait model is analogous to that of psychometric inventories, and specifically models the Metacognitive Awareness Inventory (MAI) [6]. The MAI comprises factors such as planning, information management, comprehension, evaluation and debugging. The cognitive tasks modeled are the activities that are carried out while reading academic content. The motivation behind modeling cognitive tasks is to reduce the huge effort that goes into writing adaptive behaviours. Often course creators lack the time and skills necessary to create these adaptive rules [7]. A number of course adaptation frameworks [7][8] have being developed to support the authoring of these systems. These tools separate the learner, domain and adaptation or narrative models. This approach adds overhead to service composition, as adaptation strategies can be difficult for traditional course developers to implement. With ETTHOS, this process is simplified. Rather than generating specific rules for each type of interaction, we outline a general cognitive task model. This model describes the steps a learner takes as they read through learning material. This approach has been taken in order to deal with the changing nature of adaptive content. It is commonly reported in qualitative studies that teachers possess adaptive metacognition. This ability enables them to regulate their teaching approach in response to the individual differences of each student to promote learning [9]. With ETTHOS, it is the role of the educator to create a mapping between the metacognitive strategies and the list of cognitive activities. The mapping of traits to tasks by lecturers has been carried out on the premise that educators are metacognitive professionals.

2 The ETTHOS Model

The ETTHOS (Emulating Traits and Tasks in Higher-Order Schemata) Model has been specifically designed to describe learner cognition within an eLearning environment. ETTHOS models cognitive traits and tasks. In order to model these latent processes in a measurable way, ETTHOS uses an analogy of psychologists’ schema theory [10] with object-oriented principles. In this context, a schema may be understood as a set of mental models, which are used to organize information and create predictions, inferences and expectations. ETTHOS represents both learner traits and cognitive tasks. The cognitive trait model is structured using the format of a psychometric inventory. These inventories provide us with a method to describe salient human behaviors and skills in a measurable way. Over one hundred psychometric inventories are currently available for clinical, educational and organizational evaluations e.g. 16-PF, Myers Briggs, NEO-PI. They are concerned with measurement of a number of things including numerical and verbal ability, memory, spatial relations, personality, critical thinking and metacognition [11]. We have proposed that the structure of psychometric inventories that are created through factor analysis should be realized in a technical architecture [4]. Factor analysis can be described as reducing a wide range of observed variables into a smaller set of
descriptive variables, or factors. Psychometric inventories have been used in adaptive eLearning research, but mostly for evaluation purposes or to initialize some aspect of the learner model. For example, [12] evaluated the correlation between working memory span (WM) and performance in a personalized online course. Participants with a low WM performed better with personalization. Conversely, participants identified with medium to high WM were negatively affected. The metacognitive TutorJ [13] uses the MAI as a pre-test. The architecture looks promising because it could model similar metacognitive inventories. However, their approach is tightly coupled with a learning system via deterministic and Markov statistical reasoning. Our approach is novel, because it describes inventories in a general way and the model represents the learner over time, rather than as simply an initial test score. In ETTHOS, the structure of a psychometric is used to hold the trait model. The aim of our research is to allow specific inventories that are complimentary to learning be loosely integrated with a service. A necessary step has been to include a task model.

The cognitive task model has been authored based on the extensive work of [14], which identifies and describes the sequence of strategies and responses that readers carry out consciously as they read. Successful readers actively construct knowledge as they interact with and respond to new information that is presented to them while reading. Reading a piece of academic work incorporates text, examples, diagrams and sample solutions. The limits of this model are constrained to what the individual has indicated. As individuals learn new procedures and increase their expertise the strategies become progressively more automatic. It is acknowledged that the thought processes behind reading are not always linear. Not all readers will complete each activity depending on their goal - readers engage in recursive and interactive activities. Some activities preclude others, such as skipping a section versus front to back reading. Despite these limitations, it is possible to describe the tasks in a quasi-sequential format. We have extracted 50 individual reading activities to be represented in Goby. An evaluation was carried out to assess the trends of agreement and disagreement of 10 Computer Science lecturers on how to map traits to tasks. The motivation behind this consultation was to see if it was possible to generate a mapping. Each lecturer was capable of completing the mapping task within one hour. The results pointed to patterns of agreement on which metacognitive factors are important to learner activities, however there was no statistically significant agreement. Further work needs to be done in order to discern whether it is possible to create a general mapping between metacognitive traits and learner tasks.

A high level view of the system architecture is provided in “Fig. 1” below. This includes a stereotypical init (initialization) model and the personal learner model. Each instance in the stereotype model contains information about a trait, typical population mean, or mapping that is considered true in a particular context. Dialog (prompts and questions) is triggered using a Multi-Attribute Decision-making engine. This engine is realized within a JBoss rule set that calculates the relative utility or importance of a variety of metrics. Key dimensions calculated include the rating of the task, the confidence in the rating, and a measure of recency, and the mapping. Goby uses these trait and task models, in order to inform the metacognitive notifications.
3 Discussion

Metacognitive awareness can result in a learner with a flexible cognitive strategy repertoire, meaning that the individual will be more strategic and perform better [6]. The paper has outlined the ETTHOS model, which enables learner traits to be related to learning material by linking a psychometric inventory to a list of cognitive reading activities. Currently, ETTHOS has been implemented in the Goby service using the MAI, and the learner is prompted or questioned about their cognitive strategies. However, other inventories could be executed by changing the XML resources that describe this test. A stereotype model of the MAI has been derived from a previous population study. The populations MAI means were used to initialize the learners’ models in the Goby service. Analysis of this process is currently underway and initial evaluations of the application of ETTHOS within Goby are positive, however these are outside the scope of this paper. In discussing how this approach relates to the workshop themes, there are implications for exploring how collaborative reflection can augment and improve individual learning. Although ETTHOS is currently used alongside a hypermedia learning system, the logical separation means that it could interoperate with other types of systems, such as stand-alone systems and simulation environments. In future iterations, ETTHOS will be used to interface with other services. However, there is work to be done to ensure that learning service providers offer sufficient APIs. This work is promising however, as the main requirements are that Goby can access course metadata, and for the two services to be delivered using a mashup style user-interface. An interesting outcome from the use of the population mean is that collaborative modeling can be used to promote individual reflection. In ETTHOS, by generating a group model, it has been possible to initialize a baseline cognitive user model. Rather than transitioning from individual to collaborative
learning, the state of the group is captured. Subsequently, each unique learner is initialized with a stereotypical model, which can be tuned over time. In the future, this approach could be extended to promote collaborative reflection. Currently in Goby, learners can view an open learner model of their metacognitive awareness. This lets them compare their own beliefs to the belief of the system. It could be beneficial to include an open learner model of the population, thus applying a social-constructivist approach to learning. This means that the learner could situate their progress within that of their peers, offering them feedback on their relative strengths or weaknesses.

References